DOCTORAL DISSERTATION

Input-Output Analysis of Exchange Rates and Trade

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TABLE OF CONTENTS

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Hoang Le Thu Huong

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Exchange rates have always been a highly sensitive subject in international trade. How do changes in exchange rates affect trade prices? How do changes in exchange rates affect trade flows? Or what are the equilibrium exchange rates? These are some of the crucial issues when researching about exchange rates in international economics. On the other hand, the last decades show a deeply integrated and more interdependent world economy. All countries join the global supply chain (or global value chain) as upstream or downstream. To understand which parts in the production chain are from the domestic market and which are from imports is very important in order to do more specific analysis. The input-output table gives advantages in providing such information. In this dissertation, we take full advantages of the input-output table to analyze those main issues above. The remainder of this dissertation is organized as follows:

The first chapter of this study proposes a new empirical approach to estimating the exchange rate pass-through in Japanese imports using an Input-Output analysis. We analyze how exchange rate changes are transmitted from import prices to domestic producer prices through numerous stages of production by employing the Japanese IO tables of 2000, 2005, and 2011. Henceforth, we use the exchange rate pass-through rates to do further analysis.

The next chapter, we develop a new approach to estimating the equilibrium exchange rate (EER) by using the rich information of the global input-output table. Previous studies typically employ the cointegration approach to determine the long-run equilibrium level of exchange rates, while the internal and external balance is regarded as another important criterion to determine the EER. Yoshikawa (1990, AER) proposed a different approach to the EER estimation by allowing for intermediate input coefficients and prices so that export price competitiveness can be equalized between two countries. In contrast, we develop a novel method for estimating the nominal EER without any information on the intermediate input prices. This new estimation technique enables us to estimate the EER of various countries given that the global input-output table is available for these countries. We estimate the nominal EER of ten Asian currencies and examine the deviation between actual and equilibrium levels of exchange rates.

The last chapter of this dissertation provides a method to track the sources of intermediates used in producing exports. We take advantage of the international input-output table to decompose the formation of the global supply chain. Thenceforth, we estimate how participating in global production chain affects the exchange rate elasticity of exports.

CHAPTER 1

EXCHANGE RATE PASS-THROUGH IN PRODUCTION CHAINS

APPLICATION OF INPUT-OUTPUT ANALYSIS

1. Introduction

Japanese economy has experienced a large and rapid change of the exchange rate for the last one decade. Japanese yen started to appreciate from around 120 yen vis-à-vis the U.S. dollar in mid-2007 and accelerated the pace of yen appreciation in 2008 when the Lehman Brothers collapsed. The yen hit 75.32 yen vis-à-vis the U.S. dollar, the post-war record high, in October 2011 when the Euro area fiscal crisis became more serious. From the end of 2012, however, the yen started to depreciate dramatically thanks to the Prime Minister Abe's economic stimulus package, so-called *Abenomics*. From the end of 2012 to the end of 2014, the yen depreciated against the U.S. dollar by more than 50 percent, but Japanese economy has suffered from the prolonged deflation.[1] Figure 1 presents the annual average data on the yen/U.S. dollar nominal exchange rate, Japanese import price index and producer price index from 2012 to 2014, which clearly shows that domestic producer prices are far less responsive to nominal exchange rate changes than import prices. Why has the large depreciation of the yen failed to cause an increase in domestic producer prices?

To measure the extent of price changes in response to exchange rate changes, we typically rely on the exchange rate pass-through (ERPT) approach. There have been a large number of empirical studies on the extent of ERPT into import prices and domestic prices. Stylized facts show that import prices are the most responsive to exchange rate changes, while

[1] The data of the yen-U.S. dollar exchange rates are taken from the CEIC Database.

domestic consumption prices are the least responsive to exchange rates.[2] Domestic producer prices are also typically less responsive to exchange rate changes than import prices.

The existing studies generally used a single equation model of ERPT to analyze the domestic price sensitivity to exchange rates (Campa and Goldberg, 2005; Otani *et al*., 2003). But, the single equation approach can only consider a direct relationship between domestic price and exchange rate variables, and fails to capture some transmission of exchange rate impact from upstream to downstream production prices. A vector autoregressive (VAR) model has also been widely used to investigate interactions between exchange rate and price variables. Choudhri *et al*. (2005) used the VAR analysis of ERPT to different prices for non-U.S. G-7 countries. Ito and Sato (2008) conducted the VAR analysis of ERPT for Asian countries that experienced the currency crisis in 1997-98 by including import price, producer price, and consumer price variables in the VAR model. In recent years, Shioji (2014, 2015) applied the time-varying VAR technique to the ERPT analysis to explore possible changes in the degree of ERPT to Japanese consumer prices.[3] Indeed a VAR approach is useful in examining the interactions between different price variables, but this approach cannot fully investigate the transmission from exchange rate changes to domestic price inflation through numerous production stages.

This study proposes a new approach to ERPT along production chains by using an Input-Output (IO) table. Specifically, we analyze how exchange rate changes are transmitted from import prices to domestic producer prices through numerous stages of production by employing the Japanese IO tables of 2000, 2005, and 2011. There have been only a few studies that applied an IO analysis to the ERPT question. One exception is Shioji and Uchino (2010) that examined

[2] See, for instance, Goldberg and Campa (2005), Choudhri *et al*. (2005) and Ito and Sato (2008) for the degree of responsiveness of different domestic prices to exchange rate changes.
[3] For the recent application of the time-varying parameter estimation to the ERPT analysis, see Hara *et al*. (2015).

the effect of an oil price increase on consumer goods prices of selected industries. Goldberg and Campa (2005) and Hara *et al*. (2015) also used the information from IO tables for their analysis of ERPT.

Novelty of this paper is to develop the IO analysis of ERPT. We employ the following two-stage approach. First, we estimate the single-equation model to estimate the degree of ERPT to import prices. We use the state-space model to obtain the time-varying ERPT into import price of intermediate input goods. Second, using the estimated ERPT coefficients at the first stage, we analyze how the ERPT effect is transmitted from import prices to domestic producer prices through numerous production stages at different industries. We compare the results obtained from our two-stage approach with those from conventional single-equation model. Furthermore, we conduct a panel estimation to examine the determinants of ERPT to domestic producer prices.

To anticipate the results, we demonstrate that our two-stage ERPT estimation better captures the transmission of exchange rate changes to producer prices along production chains. The estimated ERPT coefficients obtained from the two-stage approach are positive and statistically significant in most cases, which contrast markedly with the insignificant ERPT coefficients obtained from the conventional approach. More importantly, by the fixed effect panel estimation, we reveal that if manufacturing sectors tend not only to import intermediate inputs from abroad but also to export their products to foreign countries, the degree of import pass-through to producer prices increases significantly. Thus, growing international production sharing will have a positive impact on ERPT to domestic producer prices.

The rest of the paper is organized as follows. Section 2 presents the empirical methods for an IO analysis of ERPT. Section 3 shows the empirical results of ERPT to domestic producer prices. Section 4 analyzes the determinants of ERPT. Finally, Section 5 concludes this study.

2. Empirical Methods

This study proposes a new approach to ERPT to domestic producer prices by using an IO table. We employ the following two-step approach to investigate the ERPT of Japanese imports.

2.1. First Stage Estimation: State-Space Analysis of Import Pass-Through

State Space Estimation

We start the ERPT analysis by investigating the extent of pass-through from exchange rate changes to Japanese import prices. We extend the conventional import pass-through model proposed by Campa and Goldberg (2005) to the state-space model. We use the following observation and state equations, respectively, to estimate time-varying parameters:

$$\Delta \ln P_t^m = \beta_{0,t} + \beta_{1,t}\Delta \ln NEER_t + \beta_{2,t}\Delta \ln P_t^W + \beta_{3,t}\Delta \ln Y_t^{JP} + \varepsilon_t , \qquad (1)$$

$$\beta_{k,t} = \beta_{k,t-1} + \upsilon_{k,t} \quad \text{for } k = 0, 1, 2 \text{ and } 3, \qquad (2)$$

where P_t^m denotes the import price; $NEER_t$ denotes the nominal effective exchange rate; P_t^W denotes the world producer price as a proxy for the weighted average of exporting countries' production costs; Y_t^{JP} denotes the Japanese industrial production index as a proxy for Japanese real output; ε_t and υ_t respectively, denote the Gaussian disturbances with zero mean; β_t is assumed to follow a random walk process; and Δ denotes the first-difference operator.

To better capture the effect of exchange rate changes on import prices, we focus on the short-run response of import prices to the exchange rate changes. Campa and Goldberg (2005) and other previous studies tend to include lagged exchange rate variables to allow for gradual changes of import price itself in response to the exchange rate change. Indeed, ERPT covers not only a short-run price response but also medium-run price revisions by exporting firms. However, our main interest is in the direct effect of exchange rate changes on import prices and, hence, only contemporaneous exchange rate is included in the right-hand side of equation (1).

We use the state-space model to estimate the time-varying parameter of import pass-through coefficient, β_t, in equation (1). Following Kim and Nelson (1999), we obtain the maximum likelihood estimator of β_t as an initial value of time-varying coefficients using the sub-sample from 2000 to 2004. With the estimated initial value, we use the Kalman filter technique to estimate the time-varying coefficients.

Contract Currency Based NEER

To make rigorous estimation of ERPT, we use the "contract currency based NEER", first proposed by Ceglowski (2010) and developed by Shimizu and Sato (2015) and Nguyen and Sato (2015). Conventional NEER published by Bank for International Settlements (BIS) and International Monetary Fund (IMF) is calculated as a *trade* weighted average of bilateral nominal exchange rates. However, according to the Japanese Ministry of Finance, 71.1 percent of Japan's imports are invoiced in U.S. dollars, and the share of the yen accounts for just 22.6 percent of Japan's total imports in the first-half of 2015.[4] Since the third currency invoicing is very large in Japanese imports, it is not the trade-weighted NEER but the *contract currency*

[4] For the data on the invoice currency share of Japanese trade, see the website of the Ministry of Finance: http://www.customs.go.jp/toukei/shinbun/trade-st/tuuka.htm

based NEER (henceforth, contract-NEER) that may better reflect the ERPT of Japanese imports at the customs clearance stage. Since BOJ does not publish the source country breakdown data on import prices, the contract-NEER enables us to capture the weighted average of source country specific pass-through based on the exchange rate of the yen vis-à-vis the contract currency.

Suppose only three currencies are used in Japanese imports: the yen, the U.S. dollar, and the Euro.[5] Import price indices on a contract currency basis (P_{con}^{IM}) and on a yen basis (P_{yen}^{IM}) can be expressed as follows:[6]

$$P_{con}^{IM} = (P_{yen})^{\alpha}(P_{usd})^{\beta}(P_{eur})^{\gamma} \tag{3}$$

$$P_{yen}^{IM} = (P_{yen})^{\alpha}(E_{yen/usd}P_{usd})^{\beta}(E_{yen/eur}P_{eur})^{\gamma} \tag{4}$$

BOJ collects the information on the choice of contract (invoice) currency when making survey with Japanese importers at a port level. BOJ first constructs import price indices on a contract currency basis, and then converts the indices into the import price indices on a yen basis using the nominal exchange rate of the yen vis-à-vis the contract currency k ($E_{yen/k}$). Dividing equation (4) by equation (3), we obtain the following formula of the contract-NEER:[7]

$$NEER_{yen}^{Contract} = \frac{P_{yen}^{IM}}{P_{con}^{IM}} = (E_{yen/usd})^{\beta}(E_{yen/eur})^{\gamma}. \tag{5}$$

Since we use industry- or commodity-breakdown data of BOJ import prices on both yen basis and contract currency basis, we can calculate the contract-NEER by *industry* or *commodity*.

[5] The following explanation is based on Nguyen and Sato (2015).
[6] By definition, the sum of the weights in respective equations (3) and (4) is assumed to be unity.
[7] The above discussion based on the three contract (invoice) currencies can be generalized to the case of four or more contract currencies. See Nguyen and Sato (2015) for further details.

Control Variables

To measure the trading partners' production costs for Japanese imports, we need calculate a weighted average of exporting countries' producer price indices (P_t^W). Following Campa and Goldberg (2005), we collect the effective exchange rates of the yen in both nominal and real terms from BIS, and use the following formula to obtain the trading partners' production costs:

$$P_t^W = \left(\frac{NEER_t^{yen}}{REER_t^{yen}}\right) \cdot P_t^{JP} = \Pi_{k=1}^{n} (P_t^k)^{\alpha_k}, \qquad (6)$$

where P_t^{JP} denotes the Japanese PPI; P_t^k denotes the *k*-th trading partner country's PPI; α_k denotes the share of Japanese imports from *k*-th country in the total imports; and $\sum_{k=1}^{n} \alpha_k = 1$.

For Japanese real output, we use the monthly series of Japanese industrial production index that obtained from Ministry of Economy, Trade and Industry (METI), Japan.

2.2. Second Stage Estimation: Input-Output Analysis of Pass-Through to Producer Prices

The second-stage estimation of ERPT considers the transmission of changes in imported intermediate prices (expressed in domestic currency terms) to domestic producer prices. Applying the IO price analysis, we derive the equation of ERPT from import prices to domestic producer prices. The details of derivation are addressed in Appendix.[8]

Domestic producer prices vector can be expressed by the following equation

$$\mathbf{P^d} = \left(\mathbf{P^m A^m} + \mathbf{v}\right)\left(\mathbf{I} - \mathbf{A^d}\right)^{-1}, \qquad (7)$$

[8] See also Appendix Table 1 for the list of IO classification (108 industries).

where $\mathbf{P^d}$ is a row vector of domestic producer prices (endogenous variables), and $\mathbf{P^m}$ is a row vector of imported intermediate prices (exogenous variables), $\mathbf{A^d}$ is a matrix of intermediate input coefficients, $\mathbf{A^m}$ is a matrix of imported intermediate input coefficients, $\mathbf{v}$ is a row vector of value added.

Assuming no changes in the value added vector and the intermediate input coefficients, we can calculate the change of domestic producer prices vector ($\mathbf{\Delta P^d}$) in response to the change of imported intermediate prices ($\Delta\mathbf{P^m}$):

$$\mathbf{\Delta P^d} = \Delta\mathbf{P^m A^m (I - A^d)^{-1}}. \qquad (8)$$

At the first stage estimation, we obtained the time-varying ERPT coefficients, $\beta_{1,t}$ s, that reflect the extent of changes in imported intermediate prices in response to one percent change in NEER. We substitute an annual average of the estimated coefficients, $\beta_{1,t}$ s, for 2000, 2005, and 2011 into $\Delta\mathbf{P^m}$ in equation (8), which enables us to measure $\mathbf{\Delta P^d}$, a change in the domestic producer prices in response to one percent change (depreciation) in NEER in respective years.

3. Empirical Results of Exchange Rate Pass-Through

3.1. Exchange Rate Pass-Through to Import Prices

Let us first look at the estimated results of the first stage estimation, i.e., changes in ERPT to import prices over time. We took an arithmetic average of time-varying ERPT coefficients ($\beta_{1,t}$) for each industry in 2000, 2005, and 2011, which are reported in Table 1. Overall, the degree of ERPT to import prices is close to unity and statistically significant in most cases. Our estimated results show higher ERPT than those of previous studies such as Otani *et al*. (2003), which is likely due to the difference in NEER. This paper uses the contract-NEER that fully reflects the share of invoice currency in Japanese imports, while the conventional NEER is constructed using the trade weight and, hence, does not allow for the large share of U.S. dollar invoicing in Japanese imports.

3.2. Exchange Rate Pass-Through to Producer Prices

Table 2 presents the results of ERPT to domestic producer prices by the two stage estimation approach. For comparison purpose, we also estimated the ERPT coefficients using the conventional single-equation model, and the results are reported in the left-hand side of Table 2. Specifically, we conducted the state-space estimation by using producer price indices in the left-hand side of equation (1). Estimated time-varying coefficients of contract-NEER are reported in Table 2.

First, the estimated ERPT coefficients obtained from the two stage estimation approach are positive and statistically significant in most industries. In contrast, the estimated ERPT coefficients obtained from the conventional single-equation model are not statistically significant at all except for just one industry in 2000. Second, if comparing the two estimated results, the degree of ERPT coefficients obtained from the two stage estimation approach are generally much higher. The ERPT coefficients obtained from the conventional single-equation model are quite small in most cases. Third, in the case of two stage estimation approach, the estimated ERPT coefficients increase gradually from 2000 to 2011. This finding suggests growing import pass-through to domestic producer prices.

3.3. Effect of Import Price Changes on Producer Prices

We have so far discussed the degree of exchange rate transmission to domestic producer prices. But, the import price itself can increase or decrease irrespective of the nominal exchange rate changes. In this sub-section, assuming no exchange rate changes, we attempt to analyze the impact of a change in import price itself on producer prices of other industries.

Figure 2 shows that energy related products and some service sectors including electricity and gas and heat supply are the most responsive to one percent increase in oil price. In contrast, most machinery sectors tend to respond to an oil price increase only to a small extent.[9]

From the latter half of 2014, crude oil price started to decline substantially. In Figure 3, we present the simulation results of price changes in machinery sectors in response to a sharp decline in oil prices by 50 percent. Japanese major machinery sectors exhibit a decline in producer prices only by 1.0-1.8 percent in response to 50 percent fall in oil prices.

4. Determinants of Exchange Rate Pass-Through

4.1. Empirical Model

We have so far analyzed the ERPT to domestic producer prices in Japanese imports by using the two stage approach. In this section, we also empirically investigate the determinants of ERPT along both domestic and international production chains. We set up the following fixed-effect panel model.

$$ERPT_{it} = \alpha + \boldsymbol{\beta}'\mathbf{X_t} + \lambda_t + \lambda_i + \varepsilon_{it}, \qquad (9)$$

where $ERPT$ denotes the estimated coefficient of ERPT to domestic producer prices in equation (8); $\mathbf{X_t}$ denotes a vector of explanatory variables including *msy* (share of imported intermediate inputs in total input of each industry), *ExY* (export share in total output of each industry), *BL* (backward linkage[10] of each industry), and *LY* (natural logarithm of the industry's total output). *i*

[9] For the detailed results of estimation, see Appendix Table 2.
[10] See Miller and Blair (2009), p.555, for definition.

and t denote an industry and time (2000, 2005, and 2011), respectively. λ_i and λ_t denote individual fixed effect and time effect, respectively. ε_{it} is an error term. The result of Hausman test shows that the fixed effect model is more appropriate than the random effect model.

msy (a share of imported intermediate inputs in total inputs) is calculated by:

$$msy_i = \frac{\text{Import}_i}{Y_i}, \qquad (10)$$

where Import_i and Y_i denote, respectively, the total imported input amount and the total input of industry *i*.

BL (backward linkage of each industry) is calculated by:

$$BL_i = \sum_j l_{ji}, \qquad (11)$$

where l_{ji} is element of Leontief inverse matrix $(\mathbf{I} - \mathbf{A^d})^{-1}$.[11]

ExY (an export share in total output of each industry) is computed by:

$$ExY_i = \frac{\text{Export}_i}{Y_i}, \qquad (12)$$

where Export_i and Y_i denote, respectively, the export amount and the total output of industry *i*.

The data of all explanatory variables are taken from Japanese IO table for 2000, 2005, and 2011 published by Ministry of International Affairs and Communications.

[11] See Appendix

4.2. Results of Pass-Through Determinants

Table 3 presents the results of fixed effect panel estimation where both cross-section and period effects are included. Results in the left-hand side and right-hand side, respectively, focus on all sectors and only manufacturing sectors in Japan. First, Table 3 clearly shows that estimated coefficients of *msy* are positive and statistically significant. This finding is consistent with the results of Section 3, where the extent of ERPT tends to be high in the sectors related to energy and natural resources.

Second, estimated coefficients of *ExY* are not statistically significant at all, which indicates that the export share of the industry in question has no relationship with the degree of ERPT. However, the interaction effect ($msy \cdot ExY$) is positive and statistically significant in manufacturing sectors, which implies that if a sector tends not only to import more of intermediate inputs from abroad but also to export its products to foreign countries, the degree of ERPT to the sector's product price becomes higher.

Third, backward linkage (*BL*) takes positive and significant coefficient in all cases, which indicates that the broader the scope of production chains for an industry, the higher the degree of ERPT to the sector's production price. This result is reasonable, because a longer chain of production tends to have larger cumulative impact of ERPT along the production chain.

Finally, the natural log of industry's total output has positive and significant impact on the extent of ERPT, likely because industry's total outputs may reflect its economic trends.

5. Concluding Remarks

This study proposed a new approach to ERPT along production chains by using an Input-Output (IO) table. We analyzed how exchange rate changes are transmitted from import prices to domestic producer prices through numerous stages of production by employing the Japanese IO tables of 2000, 2005, and 2011. Novelty of this paper is to develop the IO analysis of ERPT. We employ the following two-stage approach. First, we estimate the single-equation model to estimate the degree of ERPT to import prices. We use the state-space model to obtain the time-varying ERPT into import price of intermediate input goods. Second, using the estimated ERPT coefficients at the first stage, we analyze how the ERPT effect is transmitted from import prices to domestic producer prices through numerous production stages at different industries. We compare the results obtained from our two-stage approach with those from conventional single-equation model. Furthermore, we conduct a panel estimation to examine the determinants of ERPT to domestic producer prices.

We demonstrated that our two-stage ERPT estimation can better capture the transmission of exchange rate changes to producer prices along production chains. The estimated ERPT coefficients obtained from the two-stage approach are positive and statistically significant in most cases, which contrast markedly with the insignificant ERPT coefficients obtained from the conventional approach. More importantly, by the fixed effect panel estimation, we revealed that if manufacturing sectors tend not only to import intermediate inputs from abroad but also to export their products to foreign countries, the degree of import pass-through to producer prices increases significantly. Thus, growing international production sharing will have a positive impact on ERPT to domestic producer prices.

Appendix

Input-Output Analysis of Exchange Rate Pass-Through

The purpose of this Appendix is to explain how to derive equation (8). Figure A1 exhibits a single-country IO table with two sectors for simplicity's sake, but the following exposition assumes there exist *n* sectors each of which produces only one good.

Figure A1. Single-Country IO Table with Two Sectors

Output / Input		Intermediate 1	Intermediate 2	Final domestic demand	Export	Total output
Domestic good	1	Z_{11}^d	Z_{12}^d	F_1^d	E_1	Y_1
	2	Z_{21}^d	Z_{22}^d	F_2^d	E_2	Y_2
Imported good	1	Z_{11}^m	Z_{12}^m	F_1^m		
	2	Z_{21}^m	Z_{22}^m	F_2^m		
Value-added		V_1	V_2			
Total input		Y_1	Y_2			

Let $\mathbf{P^d} = \begin{pmatrix} p_1^d & \dots & p_n^d \end{pmatrix}$ the price vector; p_i^d is the price of the domestic good of sector *i*. Let $\mathbf{P^m} = \begin{pmatrix} p_1^m & \dots & p_n^m \end{pmatrix}$ the price vector; p_i^m is the price of the imported good of sector *i*. Z_{ij}^d is the domestic input quantity supplied to sector *j* from sector *i*. Z_{ij}^m is the imported input quantity supplied to sector j from sector i. V is the domestic primary input components (such as wages, operating surplus, indirect taxes, subsidies) or value-added. Y is the total output/input amount.

Deriving from the columns of the IO table:

$$\begin{cases} Z_{11}^d + Z_{21}^d + \ldots + Z_{n1}^d + Z_{11}^m + Z_{21}^m + \ldots + Z_{n1}^m + V_1 = Y_1 \\ Z_{12}^d + Z_{22}^d + \ldots + Z_{n2}^d + Z_{12}^m + Z_{22}^m + \ldots + Z_{n2}^m + V_2 = Y_2 \\ \ldots \\ \ldots \\ Z_{1n}^d + Z_{2n}^d + \ldots + Z_{nn}^d + Z_{1n}^m + Z_{2n}^m + \ldots + Z_{nn}^m + V_n = Y_n \end{cases}$$

Expressing amount by quantity and price, we have:

$$\begin{cases} p_1^d z_{11}^d + p_2^d z_{21}^d + \ldots + p_n^d z_{n1}^d + p_1^m z_{11}^m + p_2^m z_{21}^m + \ldots + p_n^m z_{n1}^m + V_1 = p_1^d y_1 \\ p_1^d z_{12}^d + p_2^d z_{22}^d + \ldots + p_n^d z_{n2}^d + p_1^m z_{12}^m + p_2^m z_{22}^m + \ldots + p_n^m z_{n2}^m + V_2 = p_2^d y_2 \\ \ldots \\ \ldots \\ p_1^d z_{1n}^d + p_2^d z_{2n}^d + \ldots + p_n^d z_{nn}^d + p_1^m z_{1n}^m + p_2^m z_{2n}^m + \ldots + p_n^m z_{nn}^m + V_n = p_n^d y_n \end{cases}$$

where $Z = p \cdot z$ and $Y = p \cdot y$, z and y denote quantities of input and gross output (=gross input).

Dividing both sides with y, we have:

$$\begin{cases} p_1^d a_{11}^d + p_2^d a_{21}^d + \ldots + p_n^d a_{n1}^d + p_1^m a_{11}^m + p_2^m a_{21}^m + \ldots + p_n^m a_{n1}^m + v_1 = p_1^d \\ p_1^d a_{12}^d + p_2^d a_{22}^d + \ldots + p_n^d a_{n2}^d + p_1^m a_{12}^m + p_2^m a_{22}^m + \ldots + p_n^m a_{n2}^m + v_2 = p_2^d \\ \ldots \\ \ldots \\ p_1^d a_{1n}^d + p_2^d a_{2n}^d + \ldots + p_n^d a_{nn}^d + p_1^m a_{1n}^m + p_2^m a_{2n}^m + \ldots + p_n^m a_{nn}^m + v_n = p_n^d \end{cases}$$

where v is value-added per unit of output, $a_{ij}^d = z_{ij}^d / y_j$ is the domestic input coefficient, $a_{ij}^m = z_{ij}^m / y_j$ is the imported input coefficient.

In matrix notation, this price system can also be written as:

$$\begin{pmatrix} p_1^d & \dots & p_n^d \end{pmatrix} \begin{bmatrix} a_{11}^d & \cdots & a_{1n}^d \\ \vdots & \ddots & \vdots \\ a_{n1}^d & \cdots & a_{nn}^d \end{bmatrix} + \begin{pmatrix} p_1^m & \dots & p_n^m \end{pmatrix} \begin{bmatrix} a_{11}^m & \cdots & a_{1n}^m \\ \vdots & \ddots & \vdots \\ a_{n1}^m & \cdots & a_{nn}^m \end{bmatrix} + \begin{pmatrix} v_1 & \dots & v_2 \end{pmatrix} = \begin{pmatrix} p_1^d & \dots & p_n^d \end{pmatrix}$$

and in its compact form we have:

$$\mathbf{P^d A^d} + \mathbf{P^m A^m} + \mathbf{v} = \mathbf{P^d} \, ,$$

where $\mathbf{A^d}$ and $\mathbf{A^m}$ denote domestic input coefficient matrix and imported input coefficient matrix, respectively. Rewriting the above equation yields:

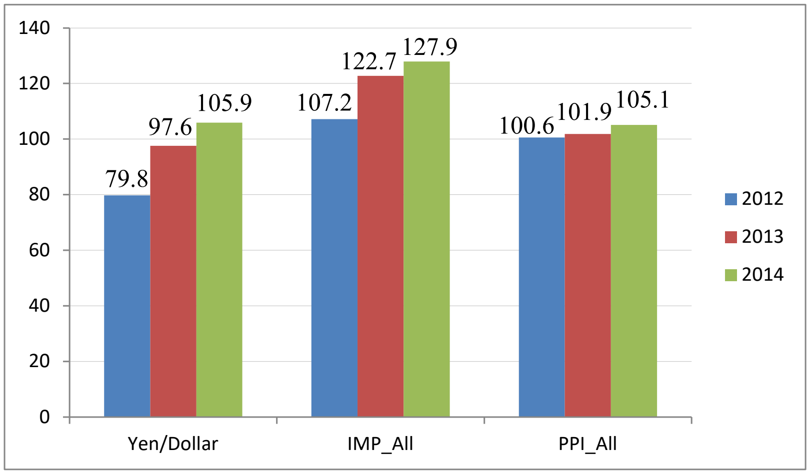
$$\mathbf{P^d} = \left(\mathbf{P^m A^m} + \mathbf{v}\right)\left(\mathbf{I} - \mathbf{A^d}\right)^{-1}$$

So when imported prices change $\Delta\mathbf{P^m}$ while the other factors are constant, the change in domestic producer prices ($\Delta\mathbf{P^d}$) is:

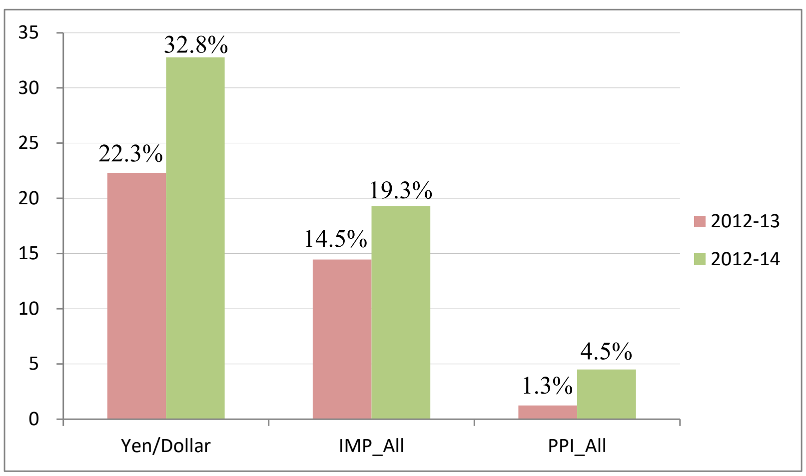
$$\Delta\mathbf{P^d} = \Delta\mathbf{P^m A^m}\left(\mathbf{I} - \mathbf{A^d}\right)^{-1} .$$

Figure 1. Changes in Nominal Exchange Rate, Import Prices, and Producer Prices

1a) Yen/Dollar Rate, IMP (2010=100), and PPI (2010=100)



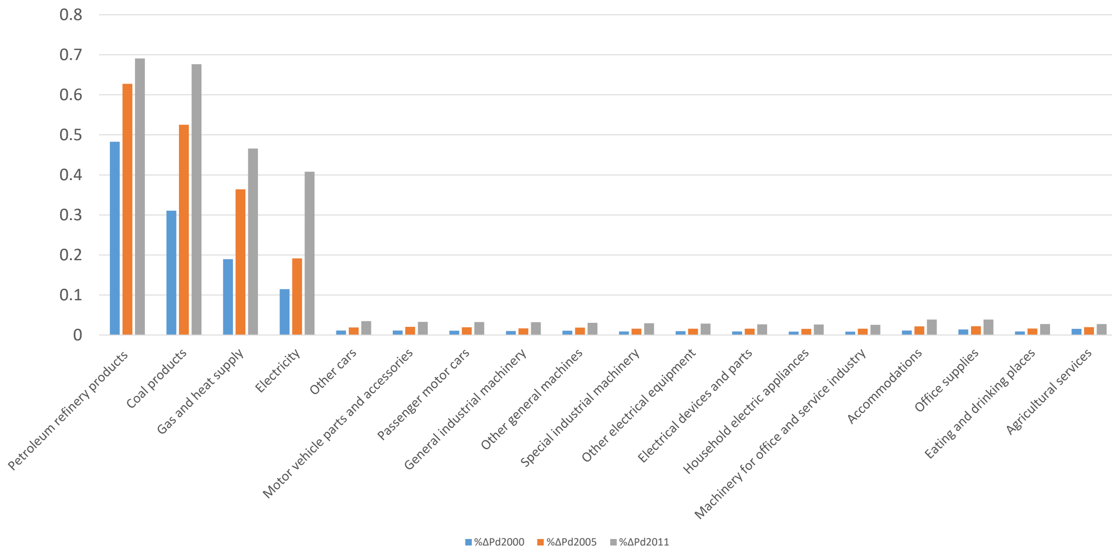
1b) Percentage Change from 2012 to 2013 and from 2012 to 2014



Note: "Yen/Dollar" denotes the nominal exchange rate of the yen vis-à-vis the U.S. dollar. "IMP_All" denotes the import price index (2010=100) of all manufacturing. "PPI_All" denotes the producer price index (2010=100) of all manufacturing.

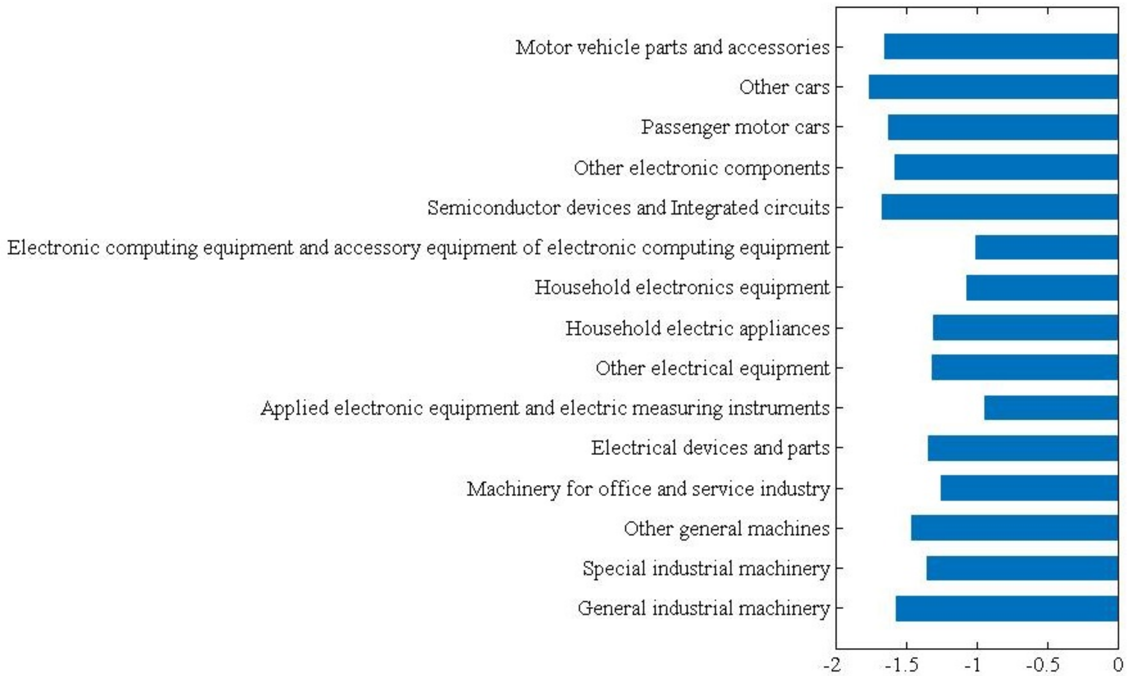
Source: Bank of Japan; and CEIC Database.

Figure 2. Effect of Oil Price Change on Domestic Producer Prices



Note: We calculate the effect of 1 percent change in the price of "coal mining, crude petroleum and natural gas" on domestic producer prices of selected industries. Vertical axis indicates percentage.

Figure 3. Effect of 50 Percent Decline in Oil Price on Domestic Producer Prices



Note: We calculate the effect of 50 percent decline in the price of "coal mining, crude petroleum and natural gas" on domestic producer prices of selected industries. Horizontal axis indicates percentage.

Table 1. Exchange Rate Pass-Through of Japanese Imports

No.	Industry:	2000	2005	2011
1	Crop cultivation	0.97 *	0.51	1.01 *
6	Metallic ores	1.18 *	0.72	2.30 *
7	Non-metallic ores	1.03 *	0.75	0.75
8	Coal mining, crude petroleum and natural gas	1.14 *	1.06	1.29
9	Foods	0.97 *	0.80 *	0.91 *
10	Beverage	0.99 *	1.05 *	0.96 *
11	Feeds and organic fertilizer, n.e.c.	1.05 *	1.01 *	0.96 *
13	Textile products	0.84 *	0.84	0.83
14	Wearing apparel and other textile products	0.87 *	0.87 *	0.87 *
15	Timber and wooden products	0.98 *	0.93 *	1.06 *
16	Furniture and fixtures	1.00 *	1.02 *	0.96 *
17	Pulp, paper, paperboard, building paper	1.12 *	1.02 *	1.31 *
18	Paper products	1.02 *	1.03 *	1.12 *
20	Chemical fertilizer	0.98 *	0.94	0.73
23	Organic chemical products (except Petrochemical basic products)	1.13 *	0.60	1.35
26	Medicaments	0.92 *	0.86 *	0.88 *
27	Final chemical products, n.e.c.	0.87 *	0.98 *	0.84 *
28	Petroleum refinery products	1.42 *	0.60	1.78 *
30	Plastic products	1.07 *	0.83 *	1.13 *
31	Rubber products	0.99 *	1.00 *	0.88 *
32	Leather, fur skins and miscellaneous leather products	1.00 *	1.01 *	1.02 *
33	Glass and glass products	1.01 *	1.09 *	0.96 *
35	Pottery, china and earthenware	0.90 *	1.13 *	0.64 *
36	Other ceramic, stone and clay products	1.01 *	0.83 *	0.98 *
37	Pig iron and crude steel	0.77 *	0.78	0.77
41	Non-ferrous metals	1.03 *	0.47	1.25 *
43	Metal products for construction and architecture	1.01 *	0.80 *	0.76 *
45	General industrial machinery	0.91 *	1.02 *	1.05 *
46	Special industrial machinery	0.98 *	1.00 *	1.04 *
47	Other general machines	1.08 *	1.31 *	1.05 *
48	Machinery for office and service industry	1.08 *	1.25 *	1.01 *
49	Electrical devices and parts	1.00 *	0.85 *	0.73
50	Applied electronic equipment and electric measuring instruments	0.98 *	0.91 *	1.15 *
52	Household electric appliances	0.95 *	1.12 *	0.82 *
53	Household electronics equipment	0.96 *	1.09 *	0.92 *
54	Electronic computing equipment and accessory equipment of electronic computing equipment	0.99 *	0.85	1.03 *
55	Semiconductor devices and Integrated circuits	1.00 *	1.08 *	1.07 *
56	Other electronic components	1.02 *	1.06 *	0.78 *
57	Passenger motor cars	0.67 *	1.06 *	0.35
58	Other cars	1.02 *	1.13 *	1.07 *
59	Motor vehicle parts and accessories	1.02 *	1.18 *	0.96 *
61	Other transportation equipment and repair of transportation equipment	1.01 *	1.00 *	1.13 *
62	Precision instruments	0.99 *	1.05 *	1.11 *
63	Miscellaneous manufacturing products	1.01 *	1.01 *	1.11 *

Note: An average of time-varying ERPT coefficients for 12 months of each year is reported. Significance level (*) is calculated based on the two standard error confidence bands. The far left column indicates the classification of IO table.

Table 2. Exchange Rate Pass-Through to Producer Prices

ERPT to Producer Prices		State Space Estimation			Two Stage Estimation		
No.	Sector	2000	2005	2011	2000	2005	2011
1	Crop cultivation	-0.132	-0.301	0.230	0.046 *	0.062	0.111
9	Foods	-0.027	-0.004	-0.040	0.110 *	0.111 *	0.188 *
10	Beverage	-0.008	0.015	0.004	0.056 *	0.061	0.127 *
11	Feeds and organic fertilizer, n.e.c.	-0.069	0.110	-0.028	0.323 *	0.235	0.528 *
13	Textile products	0.013	0.000	0.172	0.125 *	0.125	0.228
14	Wearing apparel and other textile products	-0.028	0.038	-0.032	0.094 *	0.127	0.192 *
15	Timber and wooden products	0.012	-0.002	0.069	0.067 *	0.079 *	0.142 *
16	Furniture and fixtures	0.010	-0.023	0.001	0.083 *	0.096 *	0.169 *
17	Pulp, paper, paperboard, building paper	-0.083	0.038	-0.046	0.175 *	0.175 *	0.290 *
18	Paper products	-0.002	-0.004	-0.034	0.087 *	0.097 *	0.174 *
20	Chemical fertilizer	-0.080	0.106	-0.111	0.164 *	0.220	0.270
23	Organic chemical products (except Petrochemical basic products)	0.110 *	-0.048	0.456	0.303 *	0.267	0.673
26	Medicaments	0.070	0.140	-0.873	0.058 *	0.060	0.136 *
27	Final chemical products, n.e.c.	-0.031	0.033	-0.120	0.116 *	0.121	0.302
28	Petroleum refinery products	0.325	0.108	0.565	0.552 *	0.670	0.928
30	Plastic products	0.009	0.003	-0.008	0.110 *	0.109	0.244
31	Rubber products	-0.010	0.031	-0.096	0.119 *	0.113	0.302 *
32	Leather, fur skins and miscellaneous leather products	-0.016	-0.004	-0.008	0.166 *	0.174 *	0.190 *
33	Glass and glass products	-0.022	-0.037	-0.003	0.066 *	0.078	0.171 *
35	Pottery, china and earthenware	0.005	-0.004	0.022	0.086 *	0.101	0.196 *
36	Other ceramic, stone and clay products	-0.016	0.016	-0.021	0.092 *	0.099	0.212 *
37	Pig iron and crude steel	0.100	0.121	0.715	0.250 *	0.277	0.837 *
41	Non-ferrous metals	0.475	0.263	0.645	0.407 *	0.379	1.097 *
43	Metal products for construction and architecture	0.038	-0.069	0.085	0.058 *	0.069	0.241 *
45	General industrial machinery	0.002	-0.013	-0.020	0.087 *	0.103 *	0.196 *
46	Special industrial machinery	-0.033	-0.069	-0.011	0.068 *	0.086 *	0.175 *
48	Machinery for office and service industry	-0.013	0.107	-0.046	0.103 *	0.156 *	0.198 *
49	Electrical devices and parts	-0.005	-0.018	0.133	0.074 *	0.100	0.192 *
50	Applied electronic equipment and electric measuring instruments	-0.009	0.298	-0.043	0.095 *	0.201 *	0.229 *
52	Household electric appliances	-0.013	0.288	0.247	0.114 *	0.149 *	0.216 *
53	Household electronics equipment	-0.026	0.311	0.110	0.124 *	0.206 *	0.223 *
55	Semiconductor devices and Integrated circuits	-0.029	0.168	0.126	0.064 *	0.132 *	0.210 *
57	Passenger motor cars	-0.013	-0.049	0.068	0.071 *	0.100	0.203 *
58	Other cars	-0.002	0.049	0.036	0.065 *	0.108 *	0.203 *
59	Motor vehicle parts and accessories	-0.083	0.022	-0.097	0.065 *	0.092	0.188 *
61	Other transportation equipment and repair of transportation equipment	0.035	-0.003	0.167	0.144 *	0.155 *	0.245 *
62	Precision instruments	-0.010	0.002	-0.038	0.107 *	0.098 *	0.181 *
63	Miscellaneous manufacturing products	-0.001	0.042	0.006	0.083 *	0.093	0.181 *

Note: Results of ERPT to domestic producer prices are reported. "State-Space Estimation" shows the ERPT coefficient obtained from the estimation of the conventional single equation model. “Two Stage Estimation” shows the ERPT coefficient obtained from the first stage state-space estimation and the second stage IO analysis. Significance level (*) is calculated based on the two standard error confidence bands.

Table 3. Determinants of Exchange Rate Pass-Through to Producer Prices

Dependent variable: ERPT coefficient

	All Sectors				**Manufacturing Sectors**			
VARIABLES:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IM Coeff (*msy*)	1.367***	1.532***	1.484***	1.328***	1.094***	1.425***	1.394***	1.118***
	(0.130)	(0.121)	(0.118)	(0.189)	(0.160)	(0.197)	(0.195)	(0.289)
Export/Output (*ExY*)	0.233		0.256	0.010	0.280		0.292	-0.186
	(0.202)		(0.204)	(0.138)	(0.246)		(0.256)	(0.236)
(IM Coeff)*(Export/Output)				1.603				2.890**
				(1.387)				(1.259)
Backward Linkage (*BL*)		0.139***	0.146***	0.152***		0.214**	0.220**	0.259***
		(0.049)	(0.050)	(0.045)		(0.103)	(0.099)	(0.083)
Log of Output (*LY*)	0.038*	0.043**	0.046**	0.040**	0.071**	0.080**	0.079**	0.071**
	(0.020)	(0.019)	(0.021)	(0.019)	(0.035)	(0.034)	(0.035)	(0.032)
Constant	-0.590*	-0.922***	-0.996***	-0.897***	-1.075*	-1.650***	-1.677**	-1.572***
	(0.322)	(0.318)	(0.366)	(0.330)	(0.536)	(0.550)	(0.634)	(0.575)
Cross-section Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	323	323	323	323	165	165	165	165
R-squared	0.62	0.62	0.63	0.65	0.67	0.67	0.68	0.72

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10

Table 4. List of 108 Industries

No	*Name of Sectors*	*No*	*Name of Sectors*
1	Crop cultivation	55	Semiconductor devices and Integrated circuits
2	Livestock	56	Other electronic components
3	Agricultural services	57	Passenger motor cars
4	Forestry	58	Other cars
5	Fisheries	59	Motor vehicle parts and accessories
6	Metallic ores	60	Ships and repair of ships
7	Non-metallic ores	61	Other transportation equipment and repair of transportation equipment
8	Coal mining , crude petroleum and natural gas	62	Precision instruments
9	Foods	63	Miscellaneous manufacturing products
10	Beverage	64	Reuse and recycling
11	Feeds and organic fertilizer, n.e.c.	65	Building construction
12	Tobacco	66	Repair ofconstruction
13	Textile products	67	Public construction
14	Wearing apparel and other textile products	68	Other civil engineering and construction
15	Timber and wooden products	69	Electricity
16	Furniture and fixtures	70	Gas and heat supply
17	Pulp, paper, paperboard, building paper	71	Water supply
18	Paper products	72	Waste management service
19	Printing, plate making and book binding	73	Commerce
20	Chemical fertilizer	74	Finance and insurance
21	Industrial inorganic chemicals	75	Real estate agencies and rental services
22	Petrochemical basic products	76	House rent
23	Organic chemical products (except Petrochemical basic products)	77	House rent (imputed house rent)
24	Synthetic resins	78	Railway transport
25	Synthetic fibers	79	Road transport (except transport by private cars)
26	Medicaments	80	Self-transport by private cars
27	Final chemical products, n.e.c.	81	Water transport
28	Petroleum refinery products	82	Air transport
29	Coal products	83	Freight forwarding
30	Plastic products	84	Storage facility service
31	Rubber products	85	Services relating to transport
32	Leather, fur skins and miscellaneous leather products	86	Communication
33	Glass and glass products	87	Broadcasting
34	Cement and cement products	88	Information services
35	Pottery, china and earthenware	89	Internet based services
36	Other ceramic, stone and clay products	90	Image information,character information production and distribution
37	Pig iron and crude steel	91	Public administration
38	Steel products	92	Education
39	Cast and forged steel products	93	Research
40	Other iron or steel products	94	Medical service and health
41	Non-ferrous metals	95	Social security
42	Non-ferrous metal products	96	Nursing care
43	Metal products for construction and architecture	97	Other public services
44	Other metal products	98	Advertising services
45	General industrial machinery	99	Goods rental and leasing services
46	Special industrial machinery	100	Repair of motor vehicles and machine
47	Other general machines	101	Other business services
48	Machinery for office and service industry	102	Amusement and recreational services
49	Electrical devices and parts	103	Eating and drinking places
50	Applied electronic equipment and electric measuring instruments	104	Accommodations
51	Other electrical equipment	105	Cleaning, barber shops, beauty shops and public baths
52	Household electric appliances	106	Other personal services
53	Household electronics equipment	107	Office supplies
54	Electronic computing equipment and accessory equipment of electronic computing equipment	108	Activities not elsewhere classified

Note: 108 industries are based on 2005 Japanese IO table.

Table 5. Effect of Import Price Change in "Coal Mining, Crude Petroleum and Natural Gas" on Producer Prices

No.	*Name of Sectors*	2000	2005	2011	*No.*	*Name of Sectors*	2000	2005	2011
1	Crop cultivation	0.013	0.025	0.037	55	Semiconductor devices and Integrated circuits	0.010	0.019	0.033
2	Livestock	0.012	0.018	0.028	56	Other electronic components	0.009	0.017	0.031
3	Agricultural services	0.016	0.020	0.027	57	Passenger motor cars	0.011	0.019	0.033
4	Forestry	0.013	0.017	0.032	58	Other cars	0.011	0.019	0.035
5	Fisheries	0.028	0.062	0.073	59	Motor vehicle parts and accessories	0.011	0.021	0.033
6	Metallic ores	0.037	0.054	0.062	60	Ships and repair of ships	0.013	0.026	0.042
7	Non-metallic ores	0.052	0.078	0.122	61	Other transportation equipment and repair of transportation equipment	0.009	0.020	0.029
8	Coal mining, crude petroleum and natural gas	0.018	0.026	0.044	62	Precision instruments	0.008	0.015	0.029
9	Foods	0.012	0.021	0.030	63	Miscellaneous manufacturing products	0.013	0.019	0.029
10	Beverage	0.009	0.014	0.021	64	Reuse and recycling	0.142	0.032	0.050
11	Feeds and organic fertilizer, n.e.c.	0.012	0.015	0.020	65	Building construction	0.012	0.018	0.026
12	Tobacco	0.003	0.005	0.005	66	Repair ofconstruction	0.012	0.019	0.029
13	Textile products	0.016	0.030	0.050	67	Public construction	0.021	0.036	0.054
14	Wearing apparel and other textile products	0.009	0.017	0.031	68	Other civil engineering and construction	0.015	0.026	0.036
15	Timber and wooden products	0.011	0.018	0.027	69	Electricity	0.115	0.192	0.405
16	Furniture and fixtures	0.010	0.018	0.030	70	Gas and heat supply	0.189	0.364	0.466
17	Pulp, paper, paperboard, building paper	0.030	0.044	0.084	71	Water supply	0.019	0.029	0.041
18	Paper products	0.015	0.022	0.042	72	Waste management service	0.012	0.023	0.038
19	Printing, plate making and book binding	0.009	0.014	0.029	73	Commerce	0.008	0.014	0.024
20	Chemical fertilizer	0.043	0.054	0.085	74	Finance and insurance	0.003	0.005	0.009
21	Industrial inorganic chemicals	0.034	0.050	0.089	75	Real estate agencies and rental services	0.005	0.008	0.018
22	Petrochemical basic products	0.063	0.171	0.155	76	House rent	0.003	0.004	0.008
23	Organic chemical products (except Petrochemical basic products)	0.036	0.085	0.092	77	House rent (imputed house rent)	0.001	0.001	0.003
24	Synthetic resins	0.030	0.070	0.078	78	Railway transport	0.010	0.017	0.023
25	Synthetic fibers	0.025	0.054	0.082	79	Road transport (except transport by private cars)	0.034	0.048	0.058
26	Medicaments	0.009	0.016	0.022	80	Self-transport by private cars	0.149	0.202	0.253
27	Final chemical products, n.e.c.	0.015	0.028	0.039	81	Water transport	0.018	0.039	0.054
28	Petroleum refinery products	0.483	0.628	0.697	82	Air transport	0.021	0.036	0.119
29	Coal products	0.311	0.525	0.679	83	Freight forwarding	0.013	0.017	0.030
30	Plastic products	0.016	0.027	0.037	84	Storage facility service	0.010	0.016	0.028
31	Rubber products	0.016	0.025	0.035	85	Services relating to transport	0.006	0.010	0.015
32	Leather, fur skins and miscellaneous leather products	0.008	0.014	0.021	86	Communication	0.005	0.007	0.015
33	Glass and glass products	0.022	0.032	0.054	87	Broadcasting	0.007	0.010	0.017
34	Cement and cement products	0.029	0.048	0.084	88	Information services	0.006	0.008	0.012
35	Pottery, china and earthenware	0.022	0.038	0.064	89	Internet based services	n.a.	0.009	0.015
36	Other ceramic, stone and clay products	0.024	0.039	0.069	90	Image information,character information production and distribution	0.009	0.013	0.023
37	Pig iron and crude steel	0.047	0.095	0.117	91	Public administration	0.008	0.013	0.019
38	Steel products	0.033	0.063	0.098	92	Education	0.005	0.009	0.017
39	Cast and forged steel products	0.031	0.048	0.091	93	Research	0.012	0.022	0.023
40	Other iron or steel products	0.022	0.043	0.070	94	Medical service and health	0.008	0.012	0.016
41	Non-ferrous metals	0.022	0.020	0.029	95	Social security	0.007	0.010	0.020
42	Non-ferrous metal products	0.015	0.016	0.025	96	Nursing care	0.007	0.010	0.016
43	Metal products for construction and architecture	0.013	0.024	0.046	97	Other public services	0.006	0.011	0.016
44	Other metal products	0.013	0.022	0.040	98	Advertising services	0.006	0.011	0.019
45	General industrial machinery	0.010	0.017	0.031	99	Goods rental and leasing services	0.004	0.007	0.012
46	Special industrial machinery	0.009	0.016	0.027	100	Repair of motor vehicles and machine	0.008	0.014	0.023
47	Other general machines	0.011	0.019	0.029	101	Other business services	0.004	0.006	0.011
48	Machinery for office and service industry	0.009	0.016	0.025	102	Amusement and recreational services	0.010	0.018	0.030
49	Electrical devices and parts	0.009	0.016	0.027	103	Eating and drinking places	0.009	0.016	0.027
50	Applied electronic equipment and electric measuring instruments	0.007	0.011	0.019	104	Accommodations	0.011	0.022	0.039
51	Other electrical equipment	0.010	0.016	0.026	105	Cleaning, barber shops, beauty shops and public baths	0.009	0.017	0.029
52	Household electric appliances	0.009	0.015	0.026	106	Other personal services	0.009	0.015	0.026
53	Household electronics equipment	0.008	0.013	0.021	107	Office supplies	0.014	0.022	0.038
54	Electronic computing equipment and accessory equipment of electronic computing equipment	0.007	0.012	0.020	108	Activities not elsewhere classified	0.013	0.028	0.041

Note: See Figure 2.

CHAPTER 2

EQUILIBRIUM EXCHANGE RATES IN ASIAN COUNTRIES

NEW ESTIMATION APPROACH USING THE GLOBAL INPUT-OUTPUT TABLE

1. Introduction

International economic integration has been deepening for the last few decades, which has contributed to the development of the global financial system. The process of global and regional integration also entails the risk of financial instability, which may stem from the internal and external imbalances of an economy (Isard, 1995, 2007).[12] These imbalances are one of the main causes of the economic crisis that has occurred in the past, such as the debt crisis of the Latin American countries in the 1980s, the economic crisis in Mexico (1994–1995), and the Asian currency crisis in 1997–1998. Over the past 15 years, the currencies of the countries in East Asia such as Japanese Yen, Vietnam dong, Indonesia rupiah (IDR), Philippine peso (PHP) have undergone many fluctuations, and some countries in Asia such as Vietnam, Indonesia, and Philippines experienced high inflation rate during the global financial crisis.

The exchange rates play the central role in the economy and interaction with other macroeconomic variables in an open economy. According to Williamson (1994), the equilibrium exchange rate (EER) is a measure to help achieve both the internal and external balances of an economy. A certain deviation from the EER is likely to indicate the appearance of potential risks that may destabilize the economy. Therefore, it is necessary to estimate the EER and to

[12] Internal balance is achieved when the economy reaches potential output and full employment (the unemployment rate low), while external balance is determined by a sustainable balance of payments in the medium term, i.e. the surplus/deficit of the current account is in line with the flow in/out of the capital in the long term.

investigate the degree of misalignment from the EER, which enables us to examine whether the currency is overvalued or undervalued with respect to a reference currency. Even though the estimation of EER has not been a new topic in this line of research, most existing studies typically conduct a cross-country (panel) analysis to estimate the EER by employing the data set of macroeconomic fundamentals. Such an approach, however, tends to mask the country-specific factors in EER determination.

This paper develops a new approach to estimating the EER by using the rich information of the global input-output table. Previous studies typically employ the cointegration approach to determine the long-run equilibrium level of exchange rates, while the internal and external balance is regarded as another important criterion to determine the EER. Yoshikawa (1990, AER) proposed a different approach to the EER estimation by allowing for intermediate input coefficients and prices so that export price competitiveness can be equalized between two countries. In contrast, we develop the novel method for estimating the nominal EER without any information on the intermediate input prices. This new estimation technique enables us to estimate the EER of various countries given that the global input-output table is available for these countries. We estimate the nominal EER of ten Asian currencies and examine the deviation between actual and equilibrium levels of exchange rates.

The paper is organized as follows. Section 2 presents the literature review. Section 3 discusses the empirical model. Section 4 discusses the estimated results. Finally, section 5 concludes.

2. Literature Review

The research of equilibrium exchange rates (EER) is generally divided into three schools according to different approaches. The first school includes research focused on analyzing the dynamics of the real exchange rate in the short term as well as in the long term by calculating the real exchange rate with a set of macroeconomic variables expressed through a single equation. This approach is also known as the method of behavioral equilibrium exchange rate (BEER). MacDonald (1997) and Clark and MacDonald (1999) have synthesized the studies using a single equation which relates the real exchange rate to a group of macroeconomic variables. This equation is then used to statistically estimate the equilibrium exchange rate by employing time series data of the macroeconomic variables. Elbadawi (1994) estimated the long-term equilibrium exchange rate for Chile, Ghana, and India with the fundamental economic variables including commercial conditions, differences in production capacity, degree of openness of the economy, the share of government spending in GDP, and the money supply. This approach, however, tends to mask the country-specific factors in EER determination.

The second school focuses on identifying the long-term equilibrium exchange rate to reach both internal balance and external balance. The first term of fundamental equilibrium exchange rate (FEER) was introduced by Williamson (1983). However, FEER tends to ignore the short-term cyclical factors and speculation in the foreign exchange market. In addition, the determination of the FEER usually requires the use of a panel data model for large-scale data. IMF (2006) used seven variables for calculation of the EER including fiscal balance, population factors, net foreign assets, the balance of crude oil, economic growth, and two dummy variables describing the economic crisis and standard balance of current account model. The deviation of the standard current account is considered to be the cause of the deviation of the exchange rate.

Thus, the exchange rate must be adjusted to recover the balance of the current account. The adjustment level is calculated based on the elasticity of the exchange rate to the current account. Cline and Williamson (2009) presented the results of estimating the EER under this approach and pointed out that the RMB depreciated about 40% against the dollar during the study period.

Although this result is quite consistent with the results of Coudert and Couharde (2005), the result based on the FEER approach remains controversial in that how to pose the standard current account of China and how much to revalue the RMB in order to reach the standard current account. Chinn and Wei (2008) used a large data set that includes 170 countries for the period from 1971 to 2005 and pointed out that there is insufficient evidence to increase the speed of adjustment of the current account relating to the degree of flexibility of the exchange rate mechanism. Therefore, many researchers concluded that this approach is quite good, but the application of a single standard for individual countries having different institutional conditions and policy responses for the same shock and different influential channels may not be the best choice. In fact, the relationship between the current account and other influential factors in each economy depends not only on the specific characteristics of each country but also the sensitivity of the current account to those influential factors. Regression models for each country can not be separated by these differences, even though the assumption is that the influential factors are identical. This method can not point the speed of competitiveness on import and export of each country and the fluctuations of those countries' current account balance in the context of the changes in global value chain. Therefore, the application of these methods needs to be very cautious because of the problems mentioned above.

The third school calculates EER by the method of purchasing power parity (PPP). The most common and oldest method measures the long-term EER by the difference between the nominal exchange rate and the rate of prices of two countries. The theory of PPP is often used to forecast the volatility of the exchange rate and the term PPP was first laid out by the economist Gustav Cassel of Sweden in 1918 (Isard, 2007). Yoshikawa (1990) proposed a different approach to the EER estimation by allowing for intermediate input coefficients and prices so that export price competitiveness can be equalized between two countries. His study reviewed the tradable goods of Japan and assumed a fixed ratio with 2 parameters including the input coefficient of labor and natural resources. Recently, Sato *et al*. (2012) extended the model of Yoshikawa (1990) and allowed the ability to incorporate the impact of the supply chain to determine the EER for RMB. Especially, Sato *et al*. (2012) developed an analytical framework by introducing models expressing the differences in wages, the prices of intermediate inputs, and the parameters for these factors to determine EER with an analysis based on a data set of 21 countries from which China imported raw materials for production and 18 countries from which the US imported materials for the production in the period from 1995 to 2009. However, besides two basic factors given by Yoshikawa (1990) and Sato et al. (2012), other factors need to be included in the model to better reflect regional trade in Asia which is growing including electronic parts and machinery. Therefore, this study overcomes the drawbacks of Yoshikawa (1990) and Sato et al. (2012) by adding the prices of factors of domestic production into the unit cost of the production of tradable goods.

3. Empirical Model

The equilibrium exchange rate is the long-term exchange rate that equals the purchasing power parity (PPP) of a currency in a world where all goods are traded and where markets are fully efficient (OECD's definition). Isard (2007) summarized that there are six different main approaches used to estimate equilibrium exchange rates in recent years: the purchasing power parity (hereafter PPP), PPP adjusted for Balassa-Samuelson and Penn effects, two variants of the macroeconomic balance framework, assessments based on estimated exchange rate equations, and assessments based on general equilibrium model. Driver and Westaway (2004) classified that there are three kinds of analysis based on the time horizon: short-run, medium-run and long-run.

This paper uses the PPP approach to calculate the long-run bilateral equilibrium exchange rate. We follow Yoshikawa's (1990) approach that emphasizes the role of supply factors such as productivity and wage rate. The absolute PPP hypothesis states that the exchange rate between the currencies of two countries should equal the ratio of the price levels of the two countries, while the relative PPP hypothesis states that the exchange rate should bear a constant proportionate relationship to the ratio of national price levels.[13]

The measurement of EER based on Yoshikawa (1990)

The equilibrium exchange rate proposed by Yoshikawa (1990) is the exchange rate which equalizes the price of tradable goods between a home country and a foreign country. He assumed that two inputs, labor and natural resources, are used for production, and with a fixed coefficient production function. The price of tradable good in home country is described as:

$$p = wa + p_R b \qquad (1)$$

Where w and p_R are nominal wage and natural resources' price, a and b are the labor input and the natural resources input that are necessary to produce one unit of the tradable good.

While the price of tradable good in foreign country is defined as:

[13]Isard (2007)

$$p^* = w^* a^* + p_R^* b^* \qquad (2)$$

with * denotes foreign country.

He assumed that home country (Japan) imports all the natural resources to produce tradable goods, so:

$$p_R = e p_R^* \qquad (3)$$

where p_R^* is the international price of natural resources (in terms of dollar).

If the "law of one price" in the international market holds for tradable goods then we have

$$p = e p^* \qquad (4)$$

where *e* is the nominal bilateral exchange rate.

Solve (1), (2), (3) and (4) one obtains EER as follows

$$e = \left(\frac{w}{w^*}\right)\left(\frac{a}{1 - b\frac{p_R^*}{p^*}}\right)\left(\frac{1}{a^* + b^*\frac{p_R^*}{w^*}}\right)$$

The equilibrium exchange rate depends on (i) the relative nominal wage level, (ii) the terms of trade, (iii) the technological parameters. The currency is overvalued when the EER is bigger than actual exchange rate, and undervalued when the EER is smaller than the actual exchange rate.

Followed Yoshikawa (1990), Miyagawa, Toya and Makino (2004) put services and cost of capital in production factors. Sato *et al*. (2012) used input-output table, covered a wider range with 18 intermediate inputs and 22 tradable sectors to calculate EER. However they did not include service sectors and domestic intermediate inputs in their production factors. This paper, we use all domestic and imported intermediate goods and services from all countries in the world.

Our methodology

In this section, we present how we developed Yoshikawa's approach, using all intermediate inputs while consider the difference of price and nominal wage of different manufactured sectors.

Compared with Yoshikawa (1990), our assumption is less restrictive. We consider that tradable goods are produced from labor, domestic intermediates and imported intermediates. We assume that imported intermediates are traded in terms of the export country's currency. Let *a* and *b* denote input coefficient of labor and intermediate necessary to produce one unit of a tradable good. Under the assumption of perfect competition, the price of tradable sector *i* (P_{EXi}^{h}) of home country *h* will be defined as:

$$P_{EXi}^{h} = a_{i}^{h} w_{i}^{h} + \sum_{j} b_{ji}^{h} p_{j}^{h} + \sum_{k \neq h,f} \sum_{j} b_{ji}^{kh} p_{j}^{k} e_{h/k} + \sum_{j} b_{ji}^{fh} p_{j}^{f} e_{h/f}$$

where *j* denotes intermediate sector, *f* denotes the USA, *k* denotes countries that home country imports intermediate from, e is the nominal bilateral exchange rate of home currency vis-à-vis the US dollar.

Weight the price of tradable sector *i* by the export share (ω_{i}^{h}) of itself, we have price of tradable sectors of home country as follows:

$$P_{EX}^{h} = \sum_{i} \omega_{i}^{h} P_{EXi}^{h}$$

$$P_{EX}^{h} = \sum_{i} \omega_i^h a_i^h w_i^h + \sum_{i}\sum_{j} \omega_i^h b_{ji}^h p_j^h + \sum_{i}\sum_{k\neq h,f}\sum_{j} \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} + \sum_{i}\sum_{j} \omega_i^h b_{ji}^{fh} p_j^f e_{h/f} \quad (5)$$

The price of tradable sectors in the USA is

$$P_{EX}^{f} = \sum_{i} \omega_i^f a_i^f w_i^f + \sum_{i}\sum_{j} \omega_i^f b_{ji}^f p_j^f + \sum_{i}\sum_{k\neq h,f}\sum_{j} \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} + \sum_{i}\sum_{j} \omega_i^f b_{ji}^{hf} p_j^h \Big/ e_{h/f} \quad (6)$$

Follow the law of one price, we have $P_{EX}^{h} = P_{EX}^{f} e_{h/f}$ (7)

Solve (5), (6) and (7) we obtain the equilibrium exchange rate as follows

$$\Rightarrow e_{h/f} = \frac{\sum_{i} \omega_i^h a_i^h w_i^h + \sum_{i}\sum_{j} \omega_i^h b_{ji}^h p_j^h + \sum_{i}\sum_{k\neq h,f}\sum_{j} \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} - \sum_{i}\sum_{j} \omega_i^f b_{ji}^{hf} p_j^h}{\sum_{i} \omega_i^f a_i^f w_i^f + \sum_{i}\sum_{j} \omega_i^f b_{ji}^f p_j^f + \sum_{i}\sum_{k\neq h,f}\sum_{j} \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} - \sum_{i}\sum_{j} \omega_i^h b_{ji}^{fh} p_j^f}$$

Either the rise of the nominal wage in home country or the rise of input coefficients, which means the fall of productivity in labor and technology, in home country makes the home currency depreciate, and vice versa.

In the appendix of this paper, we explain in detail the method we use to estimate the nominal EER without any information on the intermediate input prices.

To calculate the EER, it is necessary to determine a base year and in this year EER is equal to actual nominal exchange rate. We choose 2005 as base year for two reasons: 1. It is the year when China and Malaysia stopped pegging their currencies to the dollar; 2. We want to avoid the periods of two international crises, and 2004 to 2006 is the period that currencies were less volatile.

We put all 35 intermediate sectors (service sectors included) in our calculation and calculate the price of tradable goods base on 18 manufacturing industries. The data which is used for the calculation in this paper is summarized in Appendix.

4. Empirical Results

Evaluation of EER

We calculate EER of 10 Asian countries currencies vi-a-vis the US dollar from 1997 to 2012. However, China, Philippines, Indonesia and Viet Nam are only available from 2000 to 2012 due to the limitations of data.

Japan (figure 3): We find that during both crisis periods the Japan yen is quite overvalued, but the difference between EER and actual exchange rate is getting smaller after that. The movement of EER and actual nominal exchange rate are the same and in general the yen is getting appreciated overtime.

Korea (figure 4): The difference between EER and actual exchange rate is small in the period 1999-2008, but hereafter Korea won is overvalued quite large, around 40% in 2009, and it still remains until 2012.

China (figure 5): We find that the EER is actually smoother, does not fluctuate much in the case of Chinese yuan. China yuan is overvalued from 2008 until 2012 around 20%. It shows that the Chinese EER gets clearly appreciated in 2012.

Singapore (figure 6): The difference between EER and actual exchange rate is small, in both crisis periods the Singapore dollar is overvalued. It also shows a little bit overvalued trend up to 2012. In general we can say the Singapore dollar is getting appreciated.

Taiwan (figure 7): It seems that Taiwan dollar is overvalued almost time, the difference becomes bigger from 2008 and remains around 20%.

Thailand (figure 8): The Thailand bath is undervalued in 1997-2003 and overvalued in 2008-2012. After 2008 crisis, actual exchange rate shows an appreciated trend while the EER shows a depreciated trend.

Similar with Thailand, Malaysia ringgit is undervalued in the period of 1997-2003 and overvalued in 2008-2012. However, in general the EER shows a depreciated trend overtime (see figure 9).

Philippines is in the same case where we find it currency undervalued before 2005 and overvalued after 2005. It also shows the same movement of actual exchange rate and EER although the difference between them is not small. Philippines peso is overvalued around 15% in 2012. (see figure 12)

Viet Nam and Indonesia show the common trends when their EERs are largely depreciated after 2008 and the overvalued ranges are also very large (see figure 10 and 11).

After 2008 crisis, all countries' currencies are overvalued. Their currencies do not get that high value when we consider from the PPP approach.

Which factor affects the movement of equilibrium exchange rate?

In this section, we check which factor affects the movement of EER by alternately fixing each factor (a^h, w^h, a^f and w^f) to the value at the beginning of the period to calculate the simulated exchange rate (SER), and then compare with the EER. For example, if the simulated exchange rate with fixed home labor coefficient a^h is bigger than the EER, we can understand that the decrease in labor coefficient, which means the increase in labor productivity, makes the

EER appreciate. If the simulated exchange rate with fixed home wage level w^h is smaller than the EER, we know that the increase in nominal wage at home country makes the EER depreciate.

We find that the biggest factor affects the revaluation of EER is the increase of home labor productivity in the case of Singapore for all the time, China from 2007 to 2012, Japan from 2010 to 2012, Korea from 2003 to 2012, Philippines from 2007 to 2012 (see figure 13-22).

While the increase of US nominal wage affects the revaluation of EER the most in the case of Japan in 2002, 2005 and 2006, Indonesia from 2008 to 2012, Philippines from 2004 to 2007, and Thailand, Taiwan, Malaysia, Viet Nam for almost the years.

And for all countries, the rise in the labor productivity of USA makes the EER devalue the most.

5. Conclusion

In this paper, we have extended the Yoshikawa's (1990) EER estimation method, and present a new approach to calculate the EER based on the global input-output tables. By using the YNU-GIO table, we calculated the EER for ten Asian countries, which covers all manufacturing industries in tradable goods and all intermediate sectors in production. We find that Asian currencies responded differently to the global financial crisis in 2008, and all currencies are overvalued vis-à-vis the US dollar until 2012. Singapore, Korea and China have significant increase in labor productivity that is the main reason for the currency overvaluation. Compared with previous research, our estimation approach makes less restrictive assumptions, which is a strong advantage in conducting the EER analysis. Although this study focuses on Asian currencies, it may be interesting to estimate EER of other countries. This is the task for our future research.

Appendix

Let:

- h denotes home country,
- f denotes foreign country
- k denotes the countries that supply intermediates to home and foreign country
- i denotes tradable sectors, i=3,4,…,20
- j denotes intermediate sectors, j=1,2,…,35
- w: nominal wage rate,
- p: nominal price
- ω: export share
- a: labor coefficient, b : real input coefficient
- e : bilateral exchange rate
- v: value added
- Q: real output

Where:

Export share

$$\omega_i = \frac{\text{export}_\text{i}}{\text{total export}}$$

Real input coefficient

$$b_{ji}^{kh} = \frac{\text{quantity of intermediate j of country k supplied to country h's sector i}}{\text{real output of country h's sector i}} = \frac{Q_{ji}^{kh}}{Q_i^h}$$

Wage rate

$$w = \frac{\text{value added}}{\text{number of employees}}$$

Labor coefficient of each sector is calculated by

$$a = \frac{\text{number of employees}}{\text{real output}}$$

Then we have

$$wa = \frac{\text{value added}}{\text{real output}} = \frac{v}{Q} \quad \text{(a)}$$

Price of tradable sector i of home country

$$P_{EXi}^{h} = a_i^h w_i^h + \sum_j b_{ji}^h p_j^h + \sum_{k \neq h,f} \sum_j b_{ji}^{kh} p_j^k e_{h/k} + \sum_j b_{ji}^{fh} p_j^f e_{h/f}$$

Price of tradable sectors of home country

$$P_{EX}^{h} = \sum_i \omega_i^h P_{EXi}^h$$

Price of tradable sectors in home country

$$P_{EX}^{h} = \sum_i \omega_i^h a_i^h w_i^h + \sum_i \sum_j \omega_i^h b_{ji}^h p_j^h + \sum_i \sum_{k \neq h,f} \sum_j \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} + \sum_i \sum_j \omega_i^h b_{ji}^{fh} p_j^f e_{h/f} \quad (5)$$

Price of tradable sectors in foreign country

$$P_{EX}^{f} = \sum_i \omega_i^f a_i^f w_i^f + \sum_i \sum_j \omega_i^f b_{ji}^f p_j^f + \sum_i \sum_{k \neq h,f} \sum_j \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} + \sum_i \sum_j \omega_i^f b_{ji}^{hf} p_j^h \Big/ e_{h/f} \quad (6)$$

Follow the law of one price, we have $P_{EX}^h = P_{EX}^f e_{h/f}$ (7)

Insert (5) and (6) into (7) then we have:

$$(3) \Leftrightarrow \left(\sum_i \omega_i^f a_i^f w_i^f + \sum_i \sum_j \omega_i^f b_{ji}^f p_j^f + \sum_i \sum_k \sum_j \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} + \sum_i \sum_j \omega_i^f b_{ji}^{hf} p_j^h \Big/ e_{h/f} \right) e_{h/f} = \sum_i \omega_i^h a_i^h w_i^h + \sum_i \sum_j \omega_i^h b_{ji}^h p_j^h + \sum_i \sum_k \sum_j \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} + \sum_i \sum_j \omega_i^h b_{ji}^{fh} p_j^f e_{h/f}$$

$$\Leftrightarrow \left(\sum_i \omega_i^f a_i^f w_i^f + \sum_i \sum_j \omega_i^f b_{ji}^f p_j^f + \sum_i \sum_k \sum_j \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} \right) e_{h/f} + \sum_i \sum_j \omega_i^f b_{ji}^{hf} p_j^h = \sum_i \omega_i^h a_i^h w_i^h + \sum_i \sum_j \omega_i^h b_{ji}^h p_j^h + \sum_i \sum_k \sum_j \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} + \sum_i \sum_j \omega_i^h b_{ji}^{fh} p_j^f e_{h/f}$$

$$\Leftrightarrow \left(\sum_i \omega_i^f a_i^f w_i^f + \sum_i \sum_j \omega_i^f b_{ji}^f p_j^f + \sum_i \sum_k \sum_j \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} \right) e_{h/f} - \sum_i \sum_j \omega_i^h b_{ji}^{fh} p_j^f e_{h/f} = \sum_i \omega_i^h a_i^h w_i^h + \sum_i \sum_j \omega_i^h b_{ji}^h p_j^h + \sum_i \sum_k \sum_j \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} - \sum_i \sum_j \omega_i^f b_{ji}^{hf} p_j^h$$

$$\Leftrightarrow \left(\sum_i \omega_i^f a_i^f w_i^f + \sum_i \sum_j \omega_i^f b_{ji}^f p_j^f + \sum_i \sum_k \sum_j \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} - \sum_i \sum_j \omega_i^h b_{ji}^{fh} p_j^f \right) e_{h/f} = \sum_i \omega_i^h a_i^h w_i^h + \sum_i \sum_j \omega_i^h b_{ji}^h p_j^h + \sum_i \sum_k \sum_j \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} - \sum_i \sum_j \omega_i^f b_{ji}^{hf} p_j^h$$

$$\Rightarrow EER_{h/f} = \frac{\sum_i \omega_i^h a_i^h w_i^h + \sum_i \sum_j \omega_i^h b_{ji}^h p_j^h + \sum_i \sum_k \sum_j \omega_i^h b_{ji}^{kh} p_j^k e_{h/k} - \sum_i \sum_j \omega_i^f b_{ji}^{hf} p_j^h}{\sum_i \omega_i^f a_i^f w_i^f + \sum_i \sum_j \omega_i^f b_{ji}^f p_j^f + \sum_i \sum_k \sum_j \omega_i^f b_{ji}^{kf} p_j^k e_{f/k} - \sum_i \sum_j \omega_i^h b_{ji}^{fh} p_j^f} \qquad \textbf{(I)}$$

Let z_{ji}^{kh} denotes the value of country k's sector j supplied to country h's sector i

$$z_{ji}^{kh} = Q_{ji}^{kh} p_j^k$$

Then we have:

$$b_{ji}^{kh} p_j^k = \frac{Q_{ji}^{kh}}{Q_i^h} p_j^k = \frac{z_{ji}^{kh}}{Q_i^h} \qquad \text{(b)}$$

Insert (a) (b) in **(I)**

$$EER_{h/f} = \frac{\sum_i \omega_i^h v_i^h \frac{1}{Q_i^h} + \sum_i \sum_j \omega_i^h z_{ji}^h \frac{1}{Q_i^h} + \sum_i \sum_{k \neq h,f} \sum_j \omega_i^h z_{ji}^{kh} e_{h/k} \frac{1}{Q_i^h} - \sum_i \sum_j \omega_i^f z_{ji}^{hf} \frac{1}{Q_i^f}}{\sum_i \omega_i^f v_i^f \frac{1}{Q_i^f} + \sum_i \sum_j \omega_i^f z_{ji}^f \frac{1}{Q_i^f} + \sum_i \sum_{k \neq h,f} \sum_j \omega_i^f z_{ji}^{kf} e_{f/k} \frac{1}{Q_i^f} - \sum_i \sum_j \omega_i^h z_{ji}^{fh} \frac{1}{Q_f^h}}$$

or

$$EER_{h/f} = \frac{\sum_i \omega_i^h v_i^h \frac{1}{Q_i^h} + \sum_i \sum_{k \neq f} \sum_j \omega_i^h z_{ji}^{kh} e_{h/k} \frac{1}{Q_i^h} - \sum_i \sum_j \omega_i^f z_{ji}^{hf} \frac{1}{Q_i^f}}{\sum_i \omega_i^f v_i^f \frac{1}{Q_i^f} + \sum_i \sum_{k \neq h} \sum_j \omega_i^f z_{ji}^{kf} e_{f/k} \frac{1}{Q_i^f} - \sum_i \sum_j \omega_i^h z_{ji}^{fh} \frac{1}{Q_i^h}}$$

To calculate output volume (real output) Q, we need to choose a base year where law of one price is hold (price of 1 unit in foreign = 1000USD, then price of 1 unit in home = 1000e in home currency). Let X is the output of each sector in the GIO table, then we have output volume (real output) equals:

$$Q_{i,t} = \frac{X_{i,t} PPI_i^{baseyear}}{PPI_{i,t}}$$

Data sources

Producer price index, wholesale price index: Statistics Office of each country

Number of employees: Statistics Office of each country

GIO tables: YNU ReCESSA

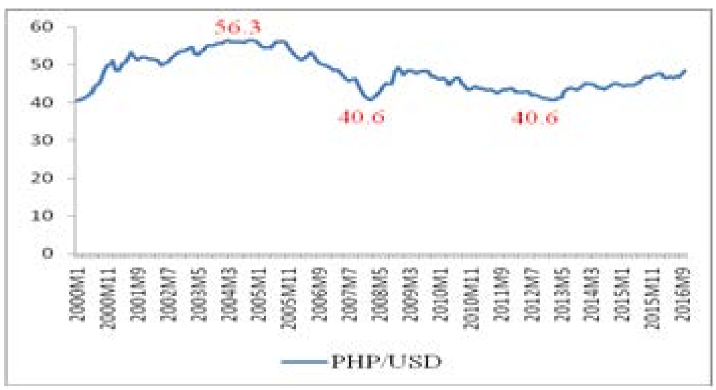
Bilateral exchange rates: International Financial Statistics (IFS)

Net trade in goods and services: World Development Indicators

Figure 1. Nominal exchange rate (Source: IFS, IMF CD-Rom)

Indonesia

Philippines



Viet Nam

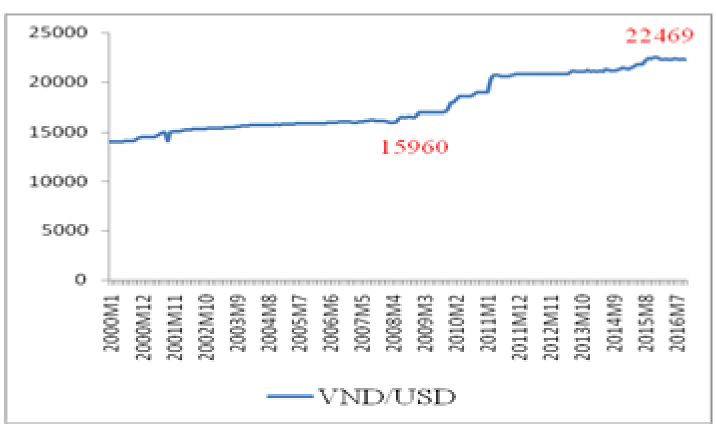


Figure 2. Inflation Rates (Source: IFS, IMF CD-Rom)

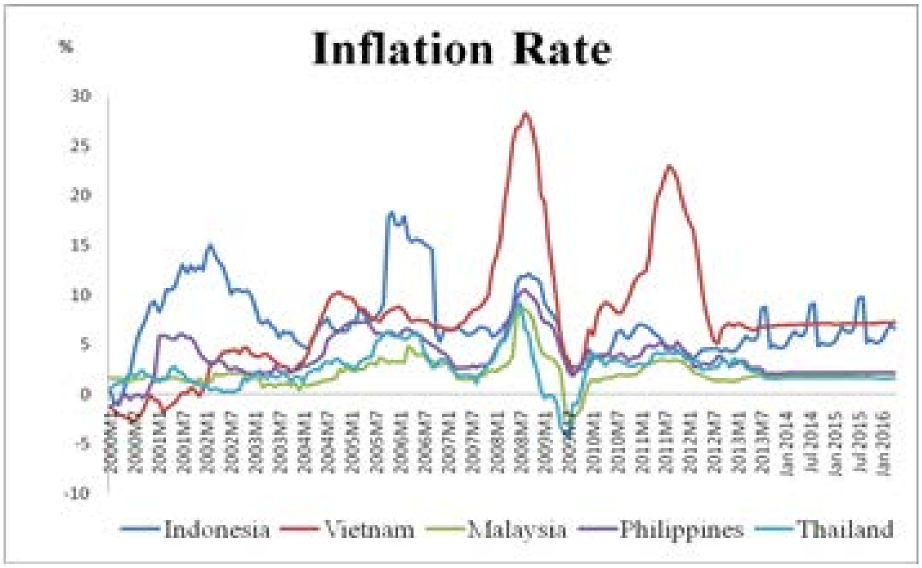


Figure 3. EER of Japan

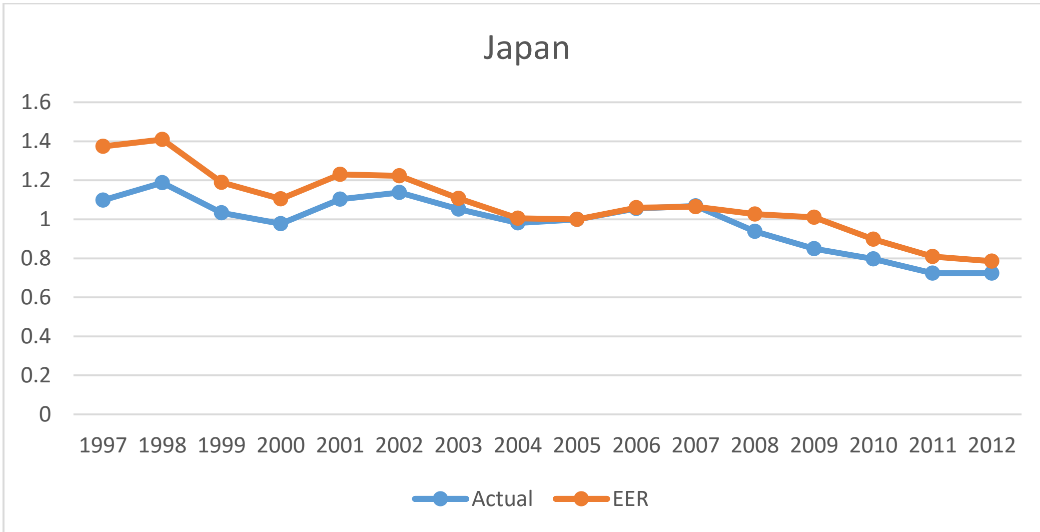


Figure 4. EER of Korea

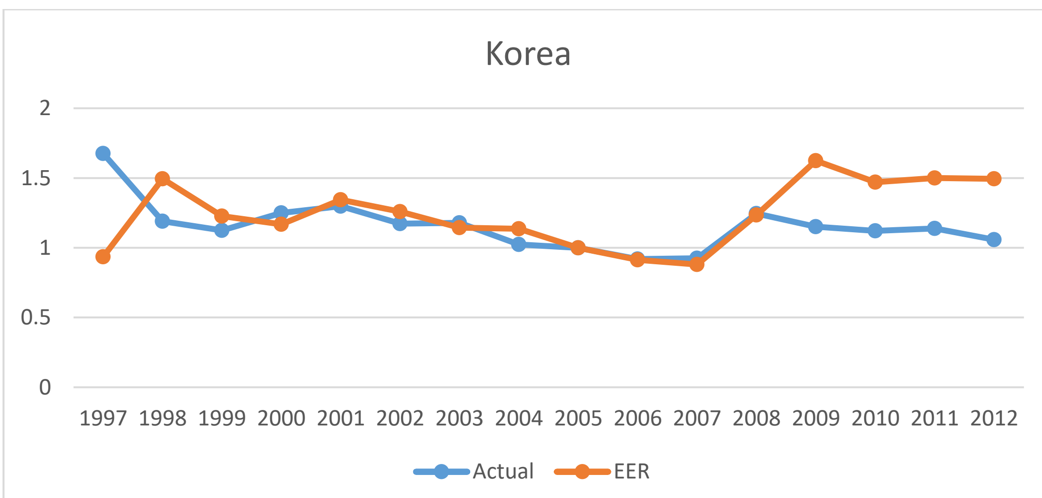


Figure 5. EER of China

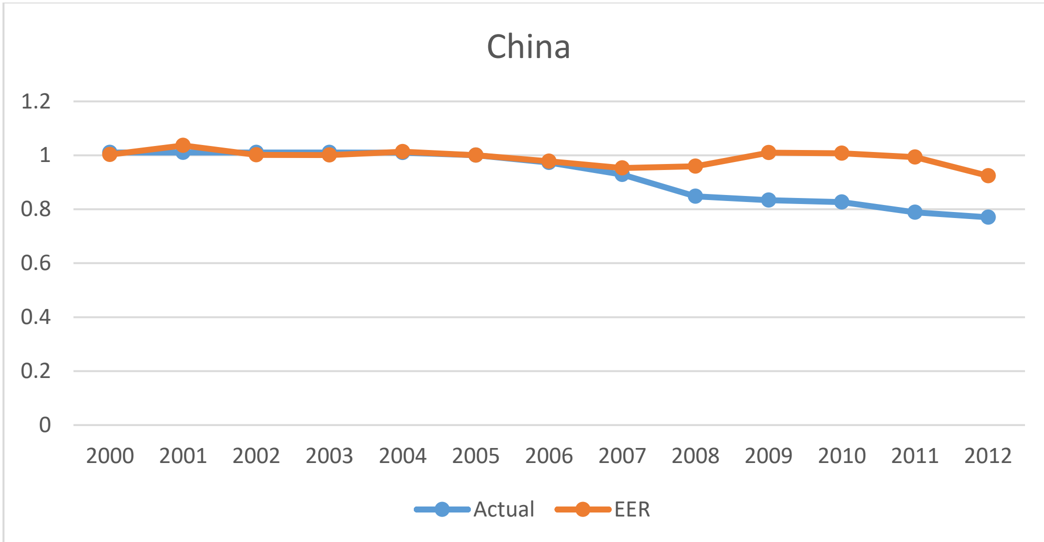


Figure 6. EER of Singapore

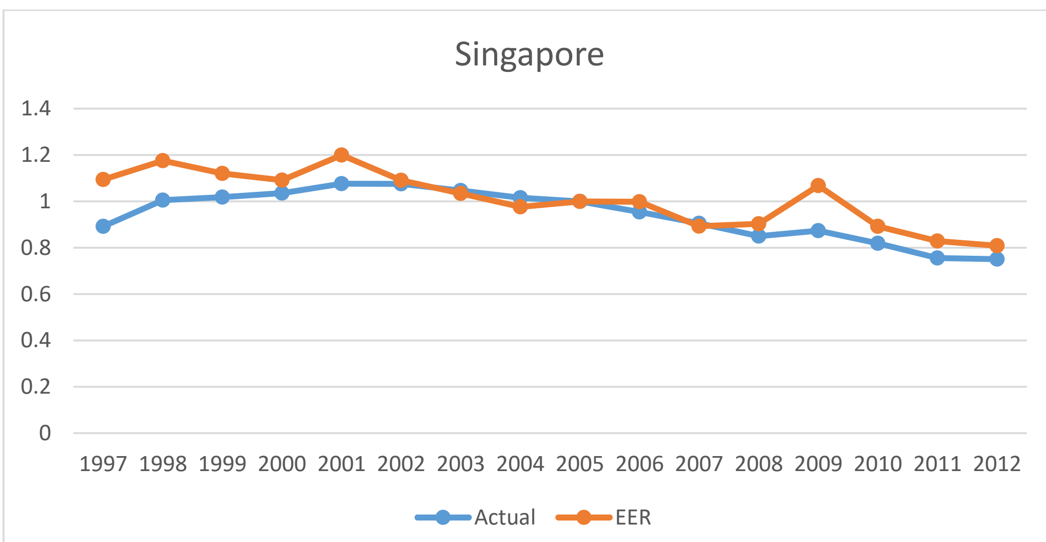


Figure 7. EER of Taiwan

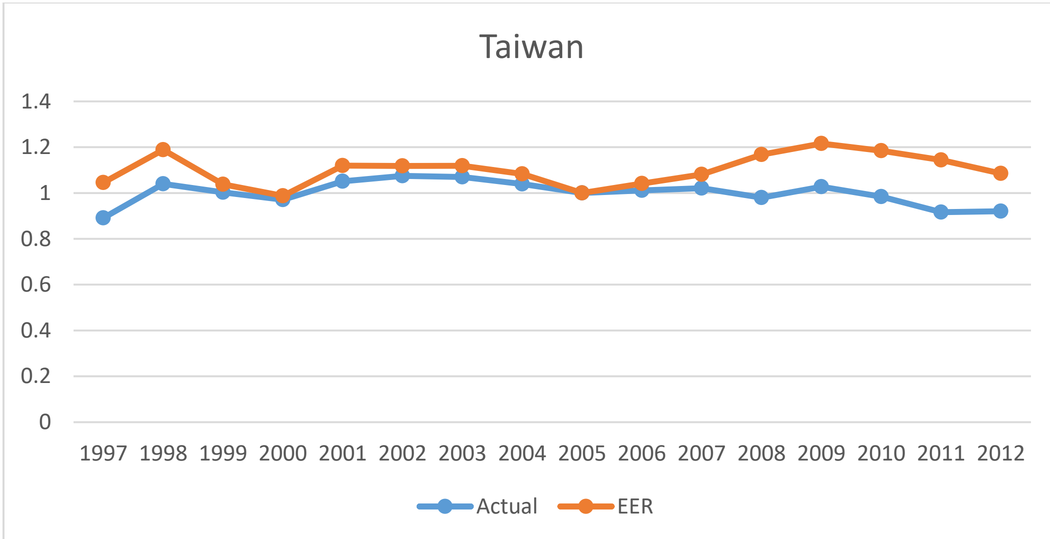


Figure 8. EER of Thailand

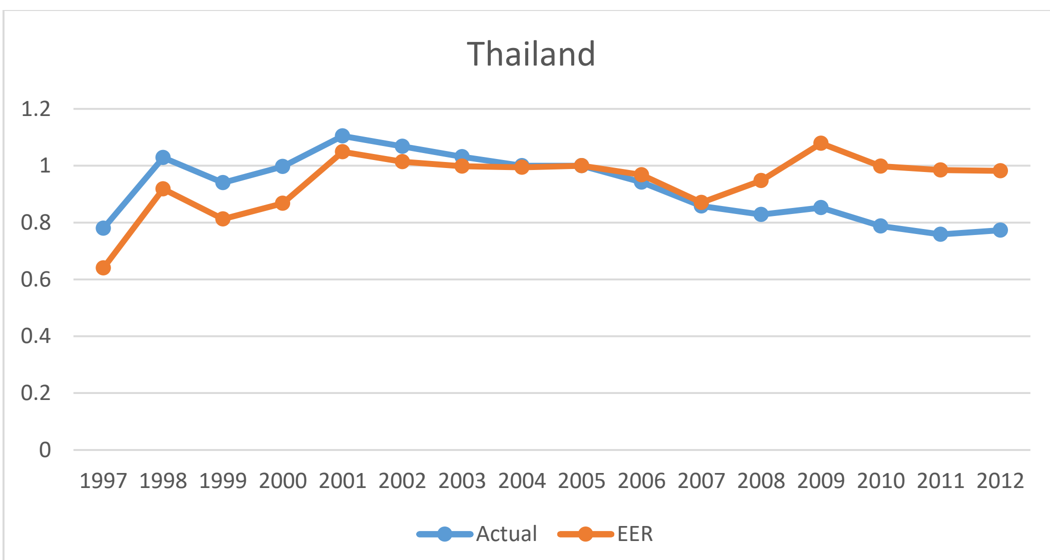


Figure 9. EER of Malaysia

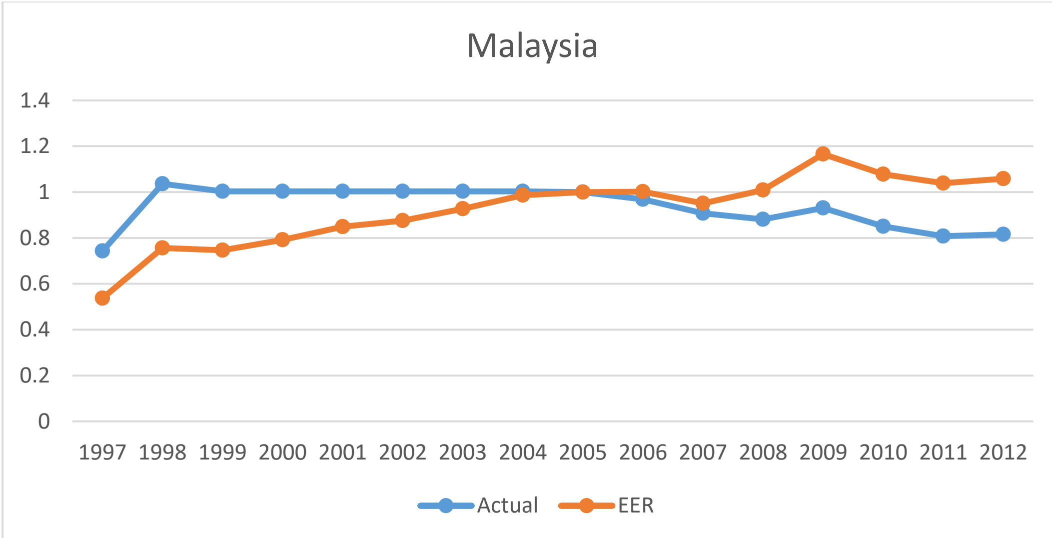


Figure 10. EER of Viet Nam

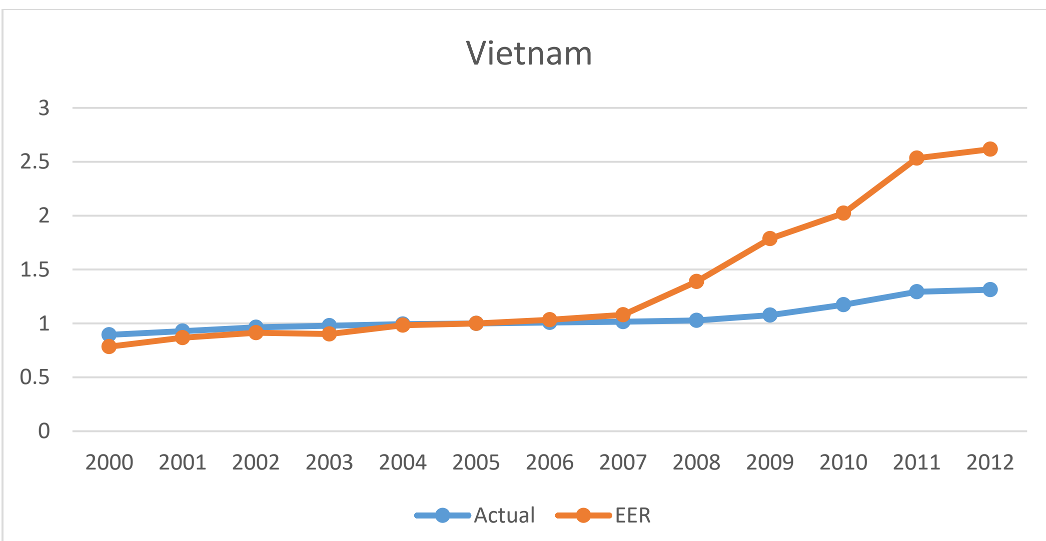


Figure 11. EER of Indonesia

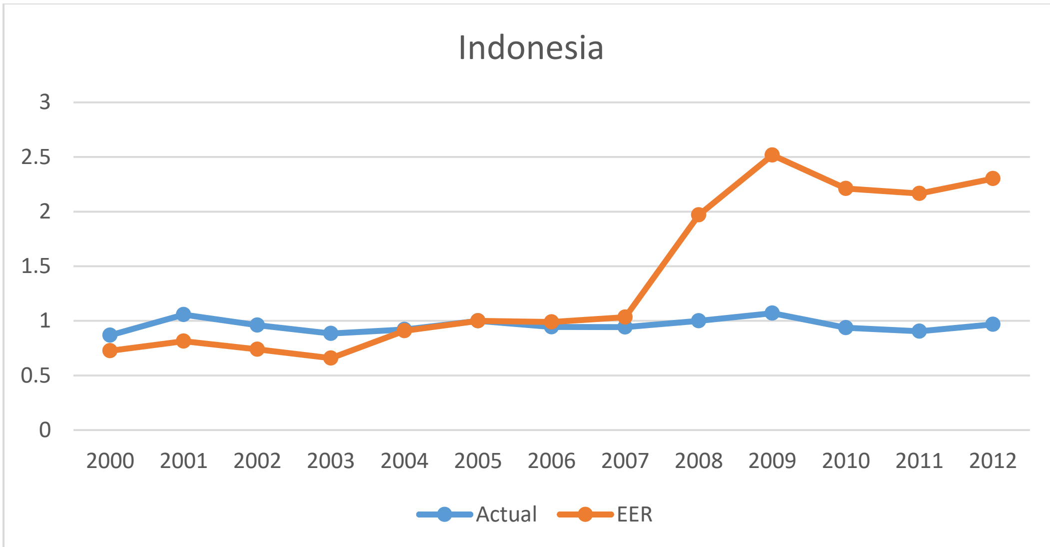


Figure 12. EER of Philippines

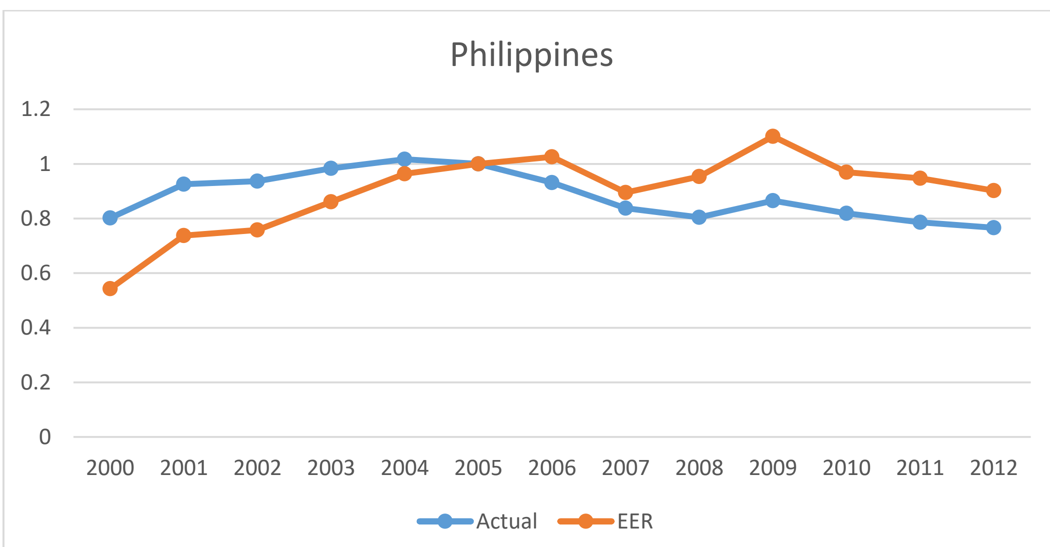


Figure 13. Simulated exchange rate of Japan

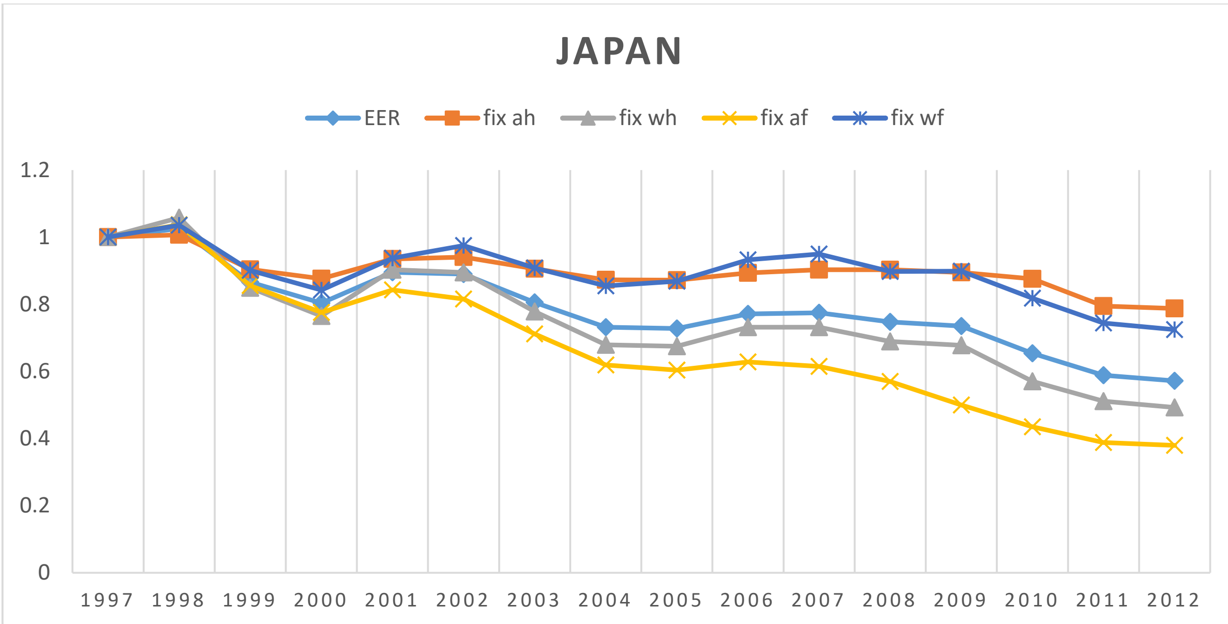


Figure 14. Simulated exchange rate of Korea

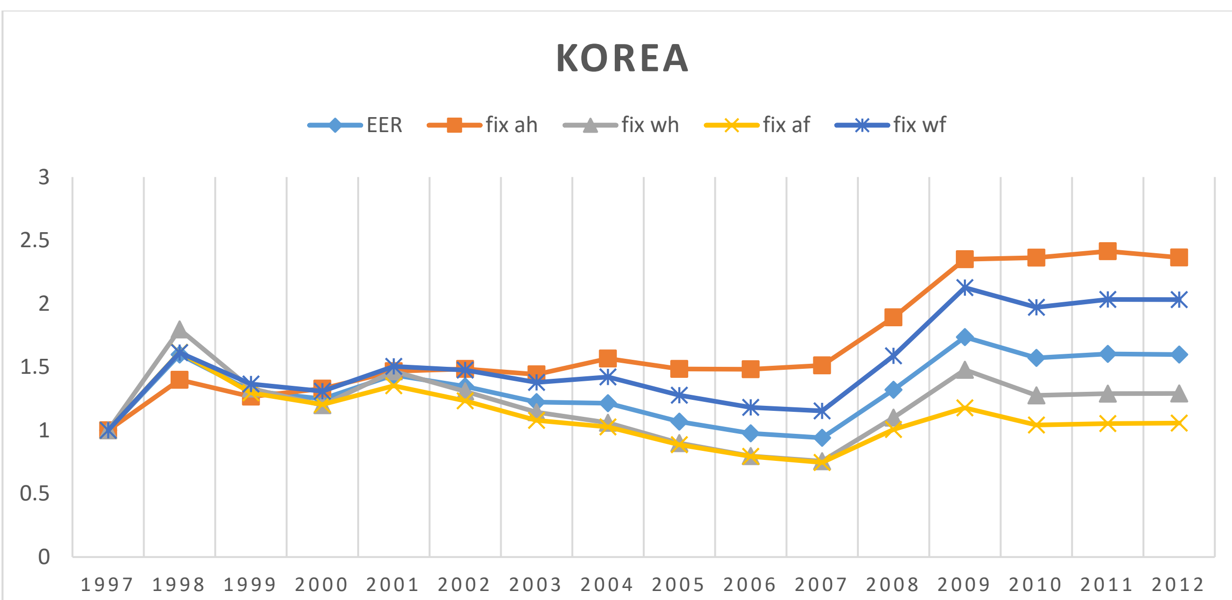


Figure 15. Simulated exchange rate of China

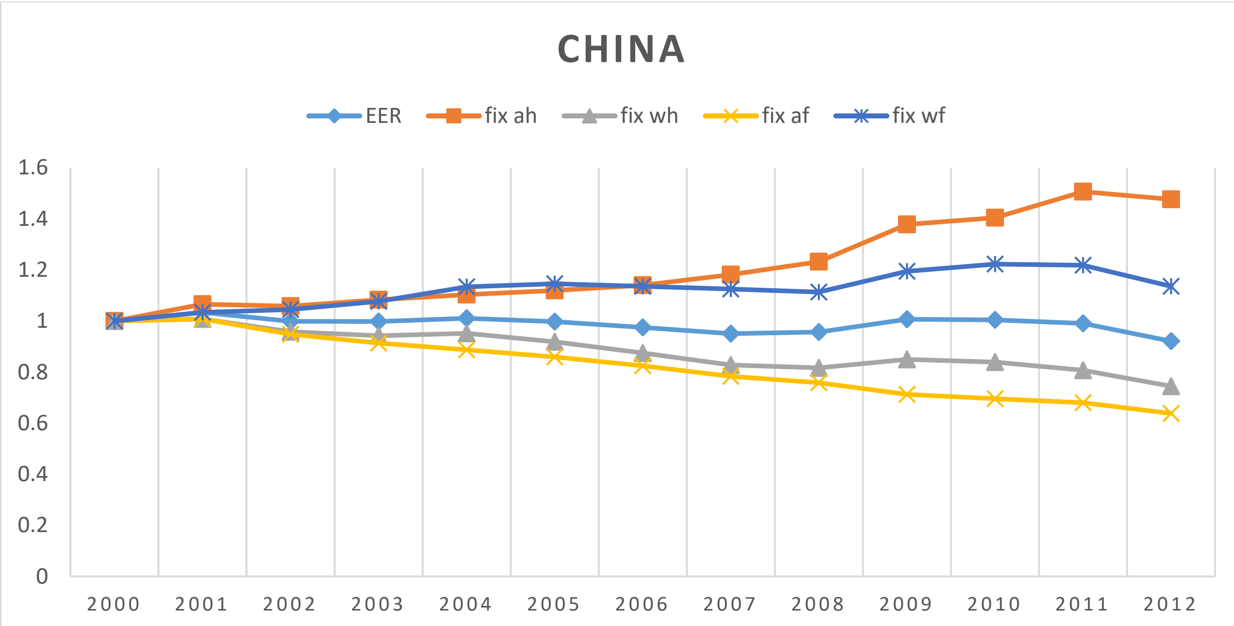


Figure 16. Simulated exchange rate of Indonesia

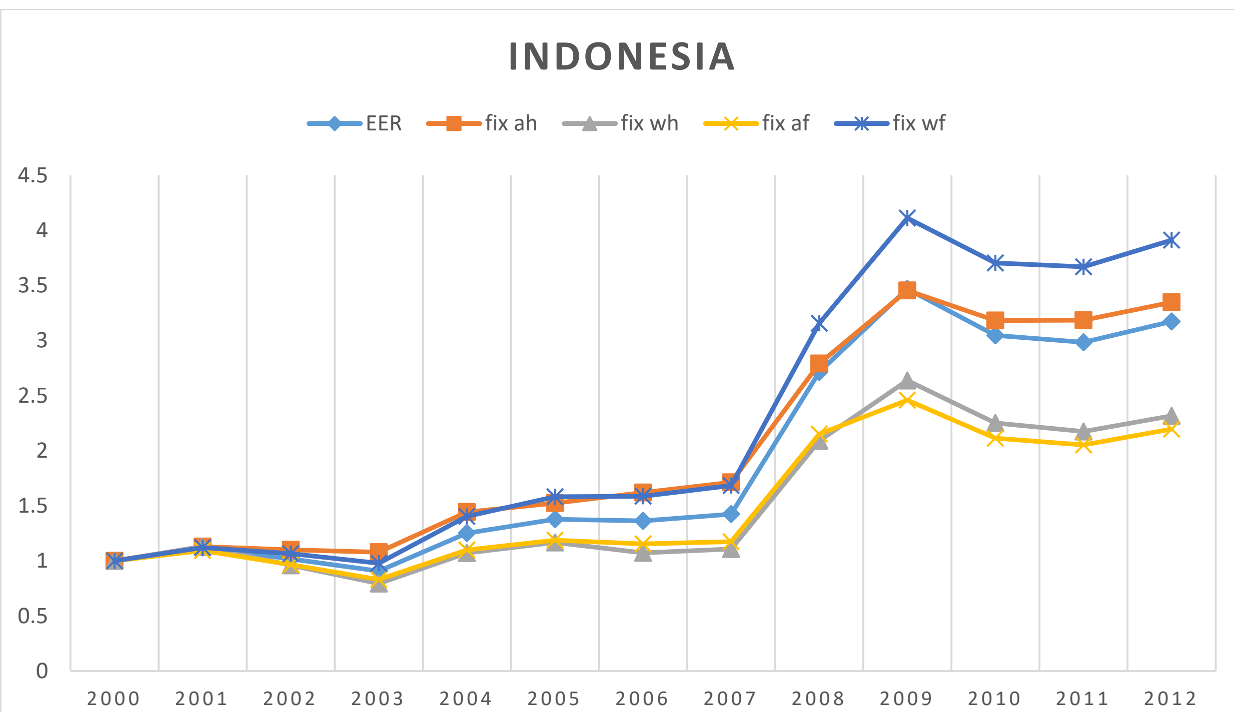


Figure 17. Simulated exchange rate of Singapore

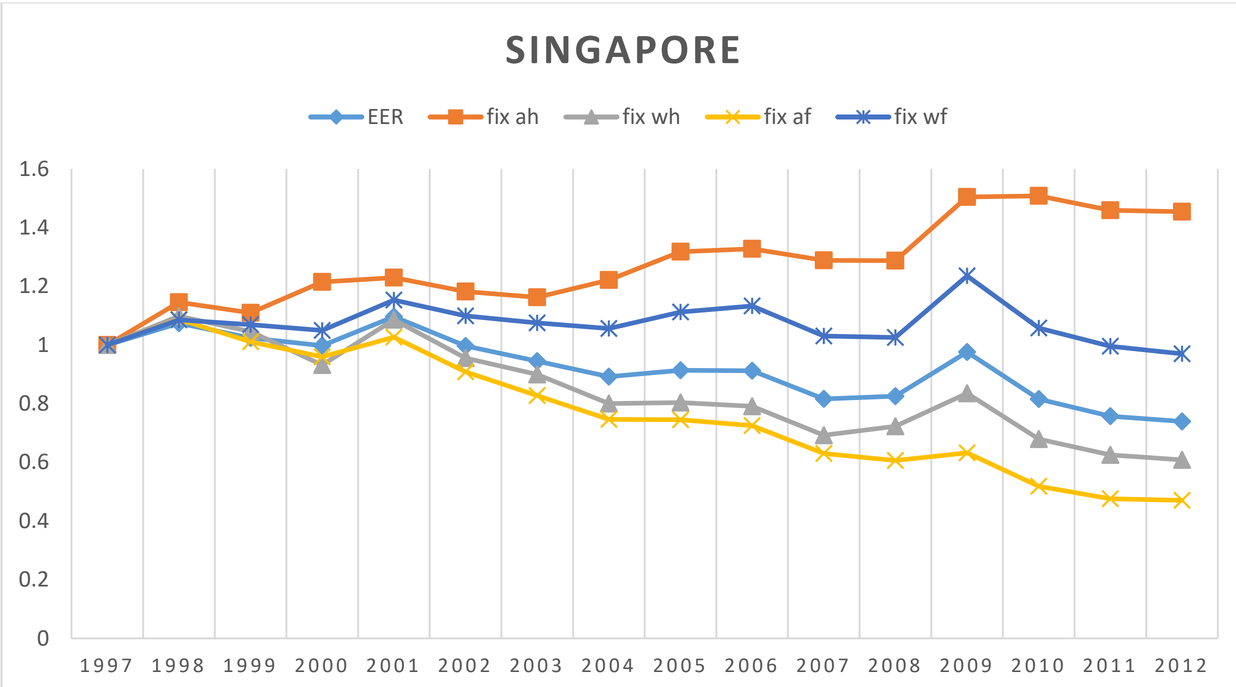


Figure 18. Simulated exchange rate of Malaysia

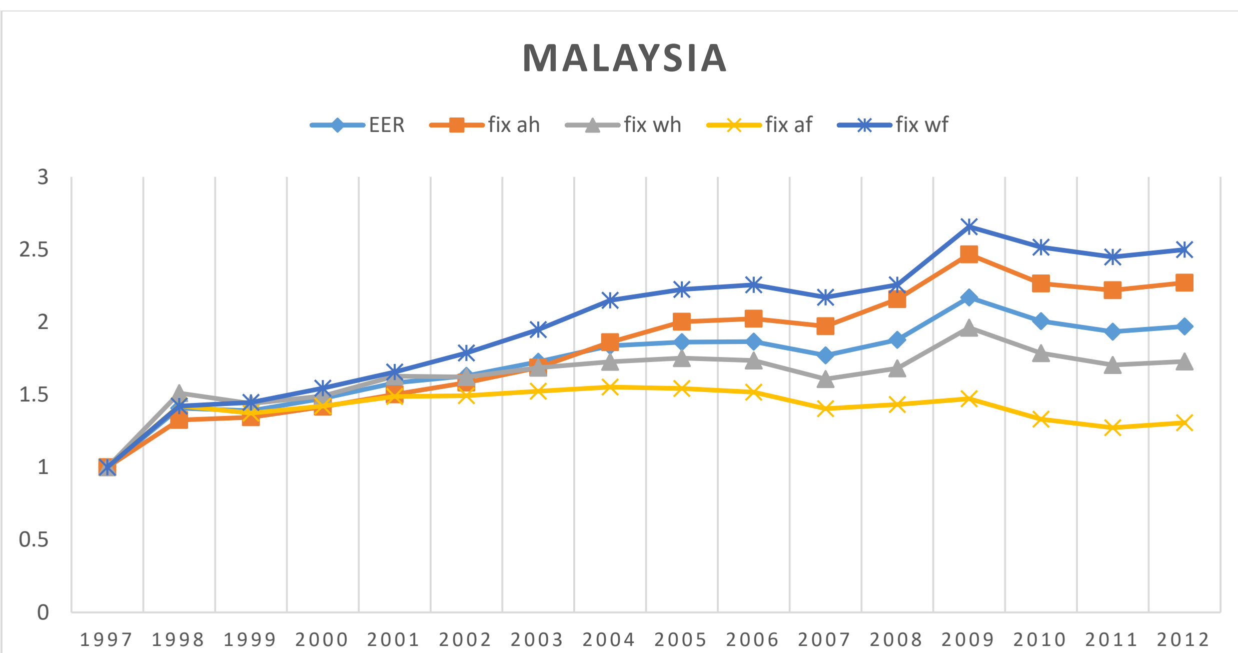


Figure 19. Simulated exchange rate of Vietnam

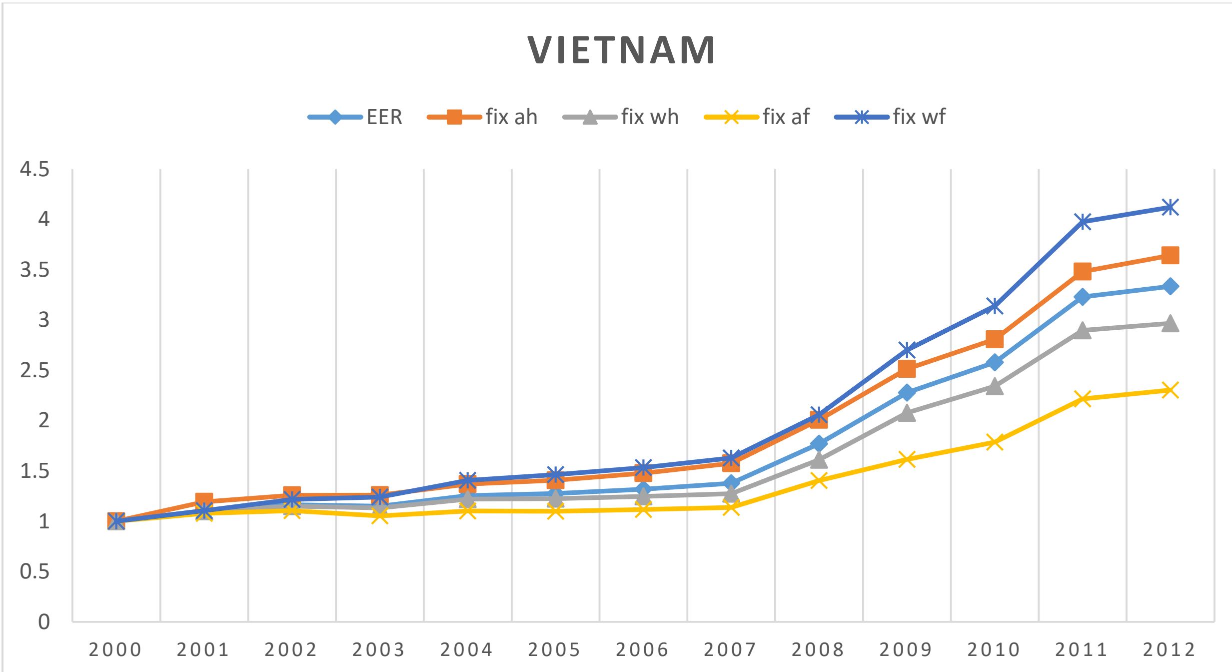


Figure 20. Simulated exchange rate of Philippines

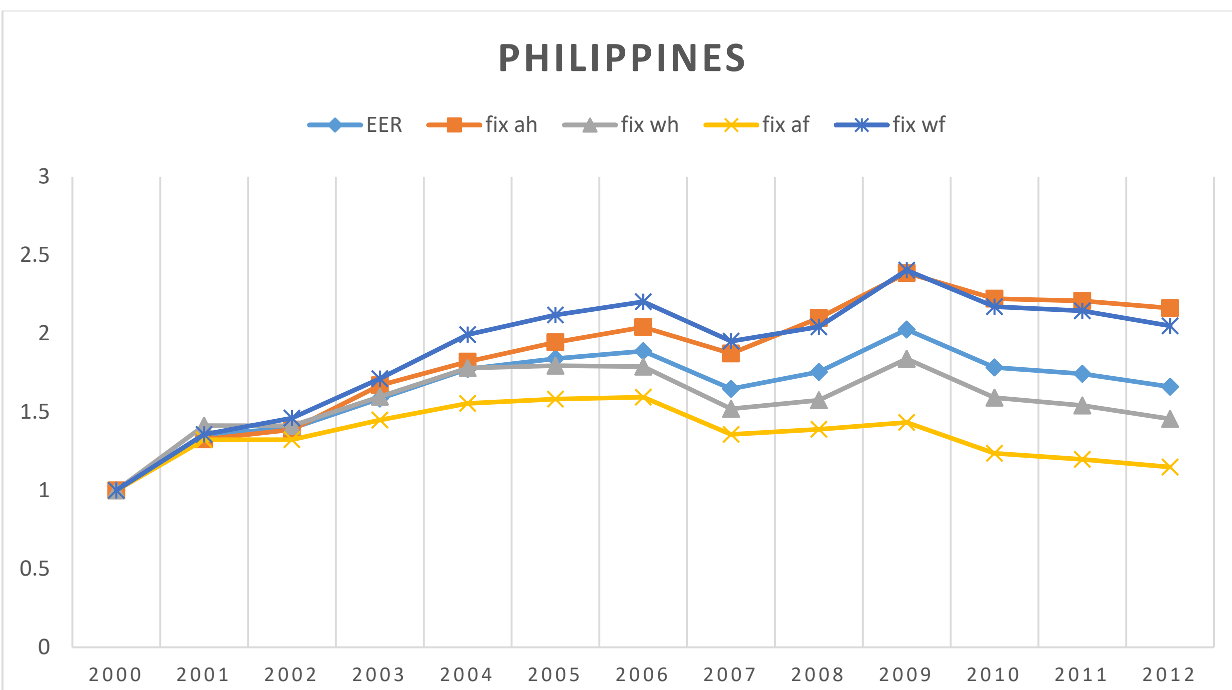


Figure 21. Simulated exchange rate of Thailand

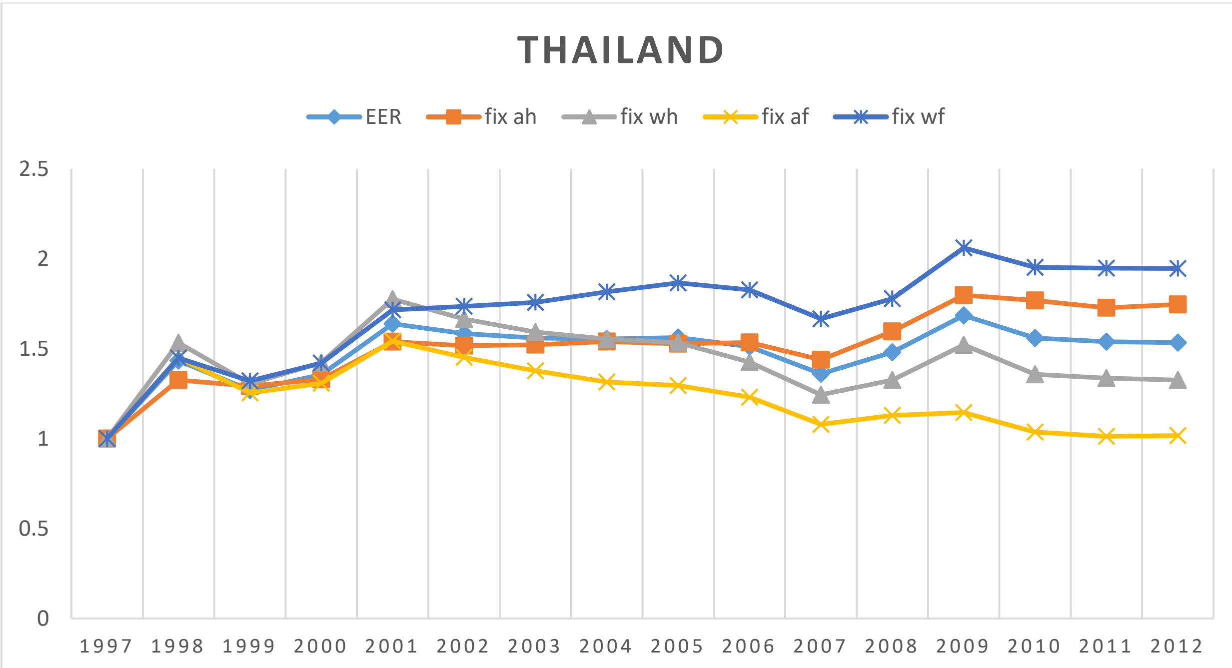


Figure 22. Simulated exchange rate of Taiwan

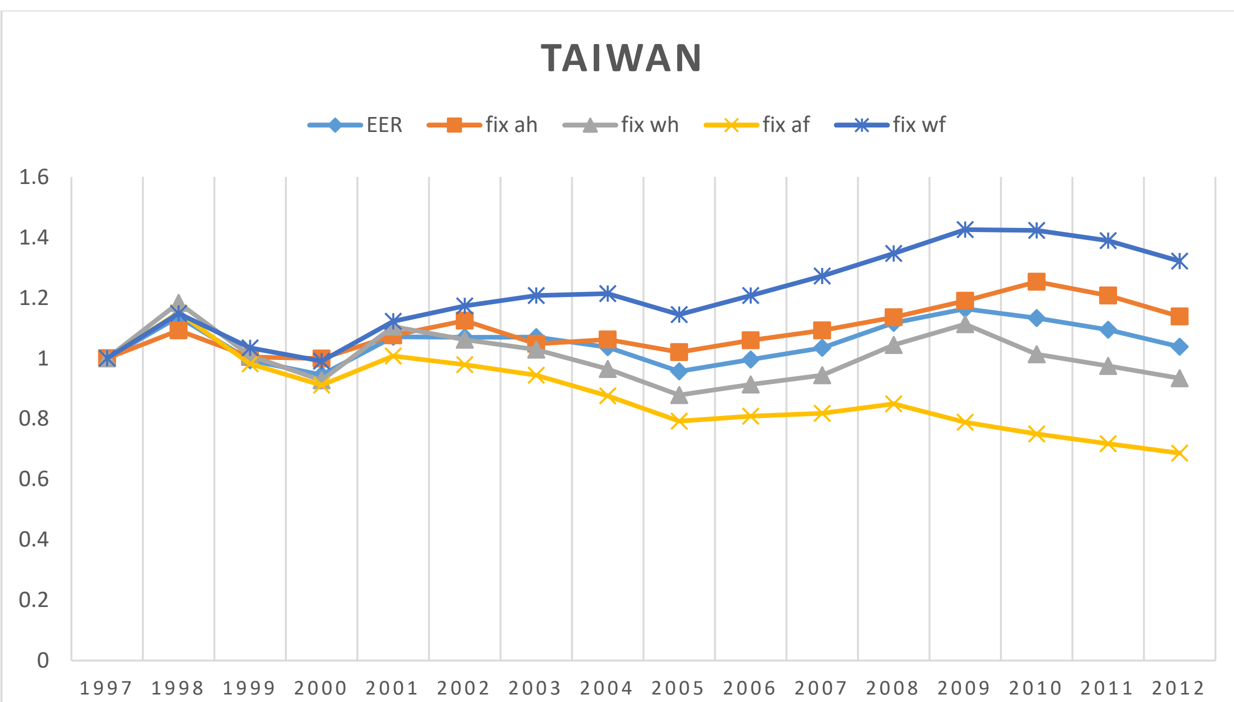


Table 1. List of sectors

1	Agriculture, hunting, forestry and fishing	19	Other transport equipment
2	Mining and quarrying	20	Other manufacturing
3	Food products, beverages and tobacco	21	Electricity, Gas and Water supply
4	Textiles, textile products, leather and footwear	22	Construction
5	Wood and products of wood and cork	23	Wholesale and retail trade; repairs
6	Pulp, paper, paper products, printing and publishing	24	Hotels and restaurants
7	Coke, refined petroleum products and nuclear fuel	25	Transport
8	Chemicals and pharmaceuticals	26	Post and telecommunications
9	Rubber and plastics products	27	Finance and insurance
10	Other non-metallic mineral products	28	Real estate activities
11	Basic metals	29	Renting of machinery and equipment
12	Fabricated metal products	30	Computer and related activities
13	Machinery and equipment	31	Research and development
14	Office, accounting and computing machinery	32	Other Business Activities
15	Electrical machinery and apparatus	33	Public administration, social security and defense
16	Radio, television and communication equipment	34	Education
17	Medical, precision and optical instruments	35	Health, social work and other services
18	Motor vehicles, trailers and semi-trailers		

Note: Tradable sectors considered in this paper are from no.3 to no.20.

CHAPTER 3

GLOBAL SPECIALIZATION AND THE EXCHANGE RATE ELASTICITY OF EXPORTS

1. Introduction

Getting more deeply integrated and interdependent is a prominent feature of the world economy nowadays. Trade in intermediate goods constitutes a large share of world trade and appears to have increased significantly in recent years. Research about the relationship between trade and exchange rate has always been an important question. With the growth of the global value chain, it is necessary to research about how it affects the relationship between exchange rate and trade.

There are two main issues in the research about the relationship between exchange rates and international trade: 1. The impact of exchange rate volatility on international trade flows; 2. The impact of currency misalignments on international trade flows. In this paper, we focus on the second issue, the relationship between the level of exchange rates and trade, and investigate how the global integration affects the exchange rate elasticity of exports.

There are two sides when considering about global production chain: intermediate goods trade and value added trade. About value added trade, in previous studies, Koopman et al. (2010) defined how much foreign and domestic value added is included in a country's export. They suggested and calculated a global value chain (GVC) participation and GVC position index. Johnson and Noguera (2012) proposed value added export ratio. Ahmed, Appendino & Ruta (2016) did a study on how the formation of global value chains has effected the relationship between the real effective exchange rate and exports. They use a panel framework with the value-added trade data which is provided by the OECD-WTO database, and only focus on manufacturing exports. However, the OECD-WTO input-output table is discontinuous so the value-added trade data is not continuous from 1995 to 2011. To deal with this problem, they use five-year average time series instead of annual time series in their panel regressions. The GVC integration they used was developed by Koopman et al. (2010). They find that as countries are more integrated in global production process, a currency depreciation only improves competitiveness of a fraction of the value of final good exports. They find that global value chain participation reduces the real effective exchange rate elasticity of manufacturing exports by 22 percent on average.

The effects of exchange rates on trades in the context of global supply chains are also addressed in several recent studies. For instance, The IMF Spillover Report on China (IMF, 2011) finds that an RMB appreciation may hurt intermediate goods producers in emerging Asia, because it lowers output in China and then lowers Chinese demand for intermediate goods. Arunachalaramanan and Golait (2011) find that an appreciation of the Chinese RMB against the India Rupee would not improve the bilateral trade balance from the Indian perspective. This is because it would raise the cost of intermediate products from China, which are very important for domestic production in India, in the short-run. On the other hand, previous studies propose that when markets have no distortions, an exchange rate misalignment, such as the undervaluation of the currency, has no long-run effect on trade flows or on real economic activity because it does not change relative prices, but the short-run can be different.

In this paper, we consider the intermediate goods trade, not the value-added trade. We look into issues such as how much imported intermediate goods a country uses and how much intermediate goods a country exports to the world. We thus analyze the relationship between participation in the global production chain through intermediate goods trade and the effect of the level of exchange rates on exports. Our objective is to find out how global integration affects the exchange rates elasticity of exports. Eichengreen & Gupta (2012) find that the effect of the real exchange rate is stronger for exports of services than exports of merchandises. They said it could be that services use fewer imported imports than merchandises. In this paper, we estimate whether fewer imported imports make the exchange rate effect on exports larger. However, different with other studies on intermediate goods trade, in this paper, we use international input-output table to track the sources of intermediate goods. Such research will capture the exact integration of countries in the global supply chain rather than considering only direct imported intermediate goods. This will be explained in more detail in the next section.

We find that if a country's exports depend more on imported intermediate goods, and if the domestic production ratio is lower, it will reduce the exchange rates elasticity of exports. This is consistent with Amiti et al. (2014) who use Belgian annual firm-level data in their analysis and find that the impact of a depreciation on export volumes is lower for exporters with higher import shares.

The remainder of this paper is organized as follows: section 2 provides the data set and the empirical methodology, section 3 contains the main empirical findings of the paper and section 4 concludes.

2. Methodology

In this section, we first decompose the global supply chain integration to find the total domestic intermediates a country produces by itself and the total foreign intermediate goods that a country imports from other countries in order to produce their goods and services for exports. Then, we estimate how the global integration affects the exchange rates elasticity of exports.

2.1. Data

Our panel includes 40 countries and covers the period 1995-2011. We use the Input-output table provided from World Input Output Database (WIOD). WIOD provides the continuous data, and especially in their input-output table, the rest of the world is considered as an endogenous country. This allows us to calculate a more exact integration of global production chain, through both intermediate goods trade and value added trade.

Real effective exchange rate (REER) data is taken from Bank for International Settlements (BIS). We use the broad index because it covers more countries. The yearly REER is calculated from monthly data. The real exchange rate (RER) we use in this paper is the inverse of the BIS's REER. An increase of RER means a depreciation of the currency and vice versa.

Real gross domestic production (RGDP) is taken from World Development Indicators (WDI) and national statistics office for the case of Taiwan. We include lagged real GDP in the regression as commonly used in the literature.

In order to calculate annual real exports time series, we transform nominal exports in terms of USD to local currency using the nominal exchange rates, and then deflate by Consumer Price Index (CPI) of each country. Nominal exchange rate of the local currency vis-à-vis USD is taken from Penn World Table, and the CPI is taken from International Monetary Fund (IMF) and national statistics office (for Taiwan).

2.2. Model

The advantage of using international input-output table is that we can track the source of intermediates to understand the specialization in the global production network. We explain how we decompose the formation of the global supply chain below.

To make it simple, we can consider the international input-output table as a single country's table. Let **x** be the N×1 vector of total output, **f** be the N×1 vector of final demand, **Z** be the N×N matrix of intermediates, **A** be the N×N input coefficient matrix (intermediate coefficient matrix), **i** is the N×1 unity vector. **A** is represented as follows:

$$\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1},$$

where a hat over a vector denotes a diagonal matrix with the elements of the vector along the main diagonal. The total output is equal to sum of intermediates and final demand. So we have:

$$\mathbf{x} = \mathbf{Zi} + \mathbf{f} = \mathbf{Ax} + \mathbf{f}.$$

Solving the above equation, we can derive the below equation:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f},$$

which shows that by knowing the final demand, one can calculate the total output of an economic system. Let $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$, the inverse matrix or the Leontief matrix[14]. Now we can represent total output as follows:

$$\mathbf{x} = \mathbf{Lf} \qquad (1)$$

On the other hand, the matrix of intermediates is represented as follows:

[14] For more detail, see Miller & Blair (2009) page 20

$$\mathbf{Zi} = \mathbf{Ax} \qquad (2)$$

Insert (1) into (2), we have:

$$\mathbf{Zi} = \mathbf{ALf} \qquad (3)$$

Let $\mathbf{D} = \mathbf{AL}$ then we can rewrite the above equation as follows:

$$\mathbf{Zi} = \mathbf{Df} \qquad (4)$$

Using this equation, we can track the sources of intermediates when given the final demand vector. In this paper, we use this equation (4) to decompose how much domestic and imported intermediates that a country needs to use to produce its exports.

For instance, let's consider an international input-output table of three countries (Table 1) and track the source of intermediates used to produce goods for exports of country 1. Let $\mathbf{f}^{12}$, $\mathbf{f}^{13}$ be the final demand exports from country 1 to country 2 and 3, respectively; and $\mathbf{e}^{1} = \mathbf{f}^{12} + \mathbf{f}^{13}$ is the final demand exports vector of country 1. The total intermediates used to produce $\mathbf{e}^{1}$ are decomposed as follows:

$$\mathbf{De}^{1} = \begin{bmatrix} \mathbf{D}^{11} & \mathbf{D}^{12} & \mathbf{D}^{13} \\ \mathbf{D}^{21} & \mathbf{D}^{22} & \mathbf{D}^{23} \\ \mathbf{D}^{31} & \mathbf{D}^{32} & \mathbf{D}^{33} \end{bmatrix} \begin{bmatrix} \mathbf{f}^{12} + \mathbf{f}^{13} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} = \begin{bmatrix} \mathbf{D}^{11}\mathbf{f}^{12} + \mathbf{D}^{11}\mathbf{f}^{13} \\ \mathbf{D}^{21}\mathbf{f}^{12} + \mathbf{D}^{21}\mathbf{f}^{13} \\ \mathbf{D}^{31}\mathbf{f}^{12} + \mathbf{D}^{31}\mathbf{f}^{13} \end{bmatrix}$$

$$\mathbf{i}'\mathbf{De}^{1} = \mathbf{u}'(\mathbf{D}^{11}\mathbf{f}^{12} + \mathbf{D}^{11}\mathbf{f}^{13}) + \mathbf{u}'(\mathbf{D}^{21}\mathbf{f}^{12} + \mathbf{D}^{21}\mathbf{f}^{13}) + \mathbf{u}'(\mathbf{D}^{31}\mathbf{f}^{12} + \mathbf{D}^{31}\mathbf{f}^{13})$$

Where **u** is the M×1 unity vector with M number of sectors (in this sample N=3M due to there are 3 countries). The first term in the second line defines the intermediates that country 1 supplies to produce goods for export of itself, the second and the third term represent respectively the intermediates that countries 2 and 3 supply to produce goods for export of country 1. The first term divided by the total intermediates is considered as the ratio of domestic intermediates. The sum of the second and the third term divided by the total intermediates is considered as the import intensive ratio.

The ratio of domestic intermediates to total intermediates used for producing exports of one country can be defined as follows:

$$dpr = \frac{\mathbf{u}'\mathbf{D}^{\mathbf{ii}}\mathbf{e}^{\mathbf{i}}}{\mathbf{i}'\mathbf{D}\mathbf{e}^{\mathbf{i}}}$$

The ratio of imported intermediates to total intermediates used for producing exports of one country is defined as follows:

$$mr = 1 - dpr = 1 - \frac{\mathbf{u}'\mathbf{D}^{\mathbf{ii}}\mathbf{e}^{\mathbf{i}}}{\mathbf{i}'\mathbf{D}\mathbf{e}^{\mathbf{i}}}$$

The *dpr* (domestic production ratio) shows that in production[15], how much one country really produces for itself. On the opposite side, the *mr* (import intensive ratio) shows how much one country relies on foreign intermediates for producing its exports. In this paper, the sum of *dpr* and *mr* is equal to 1. Thus, the bigger the *dpr*, the smaller the *mr*, and vice versa.

Next, consider the next equation:

$$\sum_{\mathbf{j=2,3}} \mathbf{D}\mathbf{e}^{\mathbf{j}} = \begin{bmatrix} \mathbf{D}^{11} & \mathbf{D}^{12} & \mathbf{D}^{13} \\ \mathbf{D}^{21} & \mathbf{D}^{22} & \mathbf{D}^{23} \\ \mathbf{D}^{31} & \mathbf{D}^{32} & \mathbf{D}^{33} \end{bmatrix} \begin{bmatrix} \mathbf{0} \\ \mathbf{f}^{21} + \mathbf{f}^{23} \\ \mathbf{f}^{31} + \mathbf{f}^{32} \end{bmatrix} = \begin{bmatrix} \mathbf{D}^{12}\mathbf{f}^{21} + \mathbf{D}^{12}\mathbf{f}^{23} + \mathbf{D}^{13}\mathbf{f}^{31} + \mathbf{D}^{13}\mathbf{f}^{32} \\ \mathbf{D}^{22}\mathbf{f}^{21} + \mathbf{D}^{22}\mathbf{f}^{23} + \mathbf{D}^{23}\mathbf{f}^{31} + \mathbf{D}^{23}\mathbf{f}^{32} \\ \mathbf{D}^{32}\mathbf{f}^{21} + \mathbf{D}^{32}\mathbf{f}^{23} + \mathbf{D}^{33}\mathbf{f}^{31} + \mathbf{D}^{33}\mathbf{f}^{32} \end{bmatrix}$$

$$\begin{aligned} \sum_{\mathbf{j=2,3}} \mathbf{i}'\mathbf{D}\mathbf{e}^{\mathbf{j}} = {} & \mathbf{u}'(\mathbf{D}^{12}\mathbf{f}^{21} + \mathbf{D}^{12}\mathbf{f}^{23} + \mathbf{D}^{13}\mathbf{f}^{31} + \mathbf{D}^{13}\mathbf{f}^{32}) + \mathbf{u}'(\mathbf{D}^{22}\mathbf{f}^{21} + \mathbf{D}^{22}\mathbf{f}^{23} + \mathbf{D}^{23}\mathbf{f}^{31} + \mathbf{D}^{23}\mathbf{f}^{32}) + \\ & + \mathbf{u}'(\mathbf{D}^{32}\mathbf{f}^{21} + \mathbf{D}^{32}\mathbf{f}^{23} + \mathbf{D}^{33}\mathbf{f}^{31} + \mathbf{D}^{33}\mathbf{f}^{32}) \end{aligned}$$

[15] In this paper we pay attention to the intermediates used only for producing exports. Hereafter it may not be mentioned but all the ratios must be put in situation of producing exports.

The first term of the second line represents the exported intermediates of country 1 that is used to produce country 2 and 3's exports. The first term divided by the total intermediates (used for producing exports of country 2 and 3) is considered as the contribution ratio of country 1 for producing exports of the rest of the world.

The ratio of exported intermediates of one country to total intermediates used to produce exports of other countries is defined as follows:

$$mer_i = \frac{\sum_{\mathbf{j \neq i}} \mathbf{u'D^{ij}e^j}}{\sum_{\mathbf{j \neq i}} \mathbf{i'De^j}}.$$

The set of the two variables, *mr* and *mer*, represents the participation level of one country in the global production chain.

A depreciation of the exchange rate makes the exports more competitive and this will help increase exports, but at the same time it makes the imports more expensive. We expect that a higher import intensive ratio will lower the exchange rate elasticity of exports.

The model we use to estimate the elasticity in this paper is as follows:

$$\Delta E_{jt} = \alpha + \beta \Delta RER_{jt} + \theta(\Delta RER_{jt} * T_{jt}) + \gamma GDP_{j,t-1} + \delta_t + \delta_j + \varepsilon_{jt}$$

Where j denotes country, t denotes year, ΔE denotes real export growth rate and ΔRER denotes real exchange rate change, *GDP* denotes real gross domestic production and *T* denotes variables that represent formation of global production chain. The country fixed effects δ_j capture the country specific growth rates, and year fixed effects δ_t capture common macro shocks that may effect the country's exports. ε_{jt} denotes the Gaussian disturbances with zero mean. We estimate the regressions with standard errors clustered at countries.

3. Empirical Results

Table 2 contains descriptive statistics for the variables used in the econometric analysis. After decomposing the formation of global production chain, we calculate *mr*, *dpr* and *mer* and report information about these variables in this table. The average domestic production ratio of all countries over the 1995-2011 period is approximately 51.64%, the highest is 90.34% and the lowest is 20.01%. It also means that the average import intensive ratio is around 48.36%, which shows that all countries are deeply interdependent with the world economy.

Figure 1 shows the domestic production ratios of all countries in 2010. We can see that the big economies such as Russia, Japan, Brazil, China, Australia, USA and Italia have a high domestic production ratio, which means low import intensive ratio and therefore do not depend much on imported intermediates. On the other hand, countries that have the lowest domestic production ratio, or depend much on imported intermediates, are small and majority belong to the EU such as Luxembourg, Hungary, Slovak Republic, Ireland or Malta.

Figure 2 shows the change of domestic production ratio over period 1995-2011 of some countries. Six of the large economies: USA, Japan, Germany, England, France and Italia seem to have lower domestic production ratio over time. Only Canada has domestic production ratio increase over time. While in BRIC, India is the only country that has domestic production ratio decrease sharply over time.

Figure 3 represents top countries that have the highest ratio of exported intermediates to total intermediates used to produce exports of other countries. It shows a clear rapid increase of China's role in the global production chain. China overtakes USA and becomes the country that supplies intermediates the most to other countries. The next three biggest countries are USA, Germany and Japan.

Table 3 shows the correlation coefficients matrix between the variables. The correlation coefficient between real export growth rate and real exchange rate change is positive and significant. It means that we can expect a positive exchange rate elasticity of exports.

Table 4 shows the results of the main regressions. Column (2) of table 4 shows that countries with a higher import intensive ratio present a lower exchange rate elasticity of exports. The exchange rate elasticity of exports is the measurement of how responsive exports are to a change in exchange rates. In other words, it shows how much exports will increase if the exchange rate increases by 1% (i.e. depreciation). The average import intensive ratio of 48.36% reduces the exchange rate elasticity of exports from 1.17 (column 1) to 0.55 (column 2). Therefore, on average, import intensive ratio reduces exchange rate elasticity of exports by approximately 52.84%.

Turning to the other variable of participation in the global production chain, we find that *mer* (ratio of exported intermediates of one country to total intermediates used to produce exports of other countries) does not have an impact on the exchange rate elasticity (see column 3 and 4 of table 4). Participating in other countries' exports more or less does not change the responsiveness of exports to real exchange rate changes.

4. Conclusion

This paper provides a method to track the sources of intermediates used in producing exports. We use the international input-output table to decompose the formation of global production chain. Thenceforth, we estimate how participating in the global production chain affects the exchange rate elasticity of exports. We find that the import intensive ratio reduces the elasticity of real exports to the real exchange rate by 52.84 percent. However, we cannot find evidence to show that participating in other countries' exports affects the elasticity of real exports to the real exchange rate. Because we can decompose to get the sources of intermediates that detail in sector level and between two countries, there is still room for research about the relationship between exchange rates and exports at a sector level or bilateral trade.

Appendix A

Table 1. An example of international input-output table of 3 countries with 2 sectors

		Intermediate						Final demand			Total output
		Country 1		Country 2		Country 3		Co. 1	Co. 2	Co. 3	
		Se. 1	Se. 2	Se. 1	Se. 2	Se. 1	Se. 2				
Co. 1	Se. 1	z_{11}^{11}	z_{12}^{11}	z_{11}^{12}	z_{12}^{12}	z_{11}^{13}	z_{12}^{13}	f_1^{11}	f_1^{12}	f_1^{13}	x_1^1
	Se. 2	z_{21}^{11}	z_{22}^{11}	z_{21}^{12}	z_{22}^{12}	z_{21}^{13}	z_{22}^{13}	f_2^{11}	f_2^{12}	f_2^{13}	x_2^1
Co. 2	Se. 1	z_{11}^{21}	z_{12}^{21}	z_{11}^{22}	z_{12}^{22}	z_{11}^{23}	z_{12}^{23}	f_1^{21}	f_1^{22}	f_1^{23}	x_1^2
	Se. 2	z_{21}^{21}	z_{22}^{21}	z_{21}^{22}	z_{22}^{22}	z_{21}^{23}	z_{22}^{23}	f_2^{21}	f_2^{22}	f_2^{23}	x_2^2
Co. 3	Se. 1	z_{11}^{31}	z_{12}^{31}	z_{11}^{32}	z_{12}^{32}	z_{11}^{33}	z_{12}^{33}	f_1^{31}	f_1^{32}	f_1^{33}	x_1^3
	Se. 2	z_{21}^{31}	z_{22}^{31}	z_{21}^{32}	z_{22}^{32}	z_{21}^{33}	z_{22}^{33}	f_2^{31}	f_2^{32}	f_2^{33}	x_2^3
Value added		v_1^1	v_2^1	v_1^2	v_2^2	v_1^3	v_2^3				
Total input		x_1^1	x_2^1	x_1^2	x_2^2	x_1^3	x_2^3				

Table 2: Summary statistics

Variable	No. Obs.	Mean	Std. Dev.	Max	Min
Growth rate of real exports	640	0.047391	0.180304	2.00765	-2.30479
RER, percent change	640	-0.00936	0.070907	0.748412	-0.38412
Dpr	680	0.516373	0.161118	0.903369	0.200059
Mer	680	0.009298	0.013923	0.084973	4.19E-05
Import intensive ratio (*mr*)	680	0.483627	0.161118	0.799941	0.096631
Log of real GDP (*lrgdp*)	680	26.5679	1.742629	30.35232	22.41281

Table 3: Correlation matrix

	ΔE	ΔRER	dpr	mer	mr	lrgdp
ΔE	1					
ΔRER	0.1325***	1				
dpr	-0.0505	0.0111	1			
mer	-0.0247	0.0683*	0.5018***	1		
mr	0.0505	-0.0111	-1.000***	-0.5018***	1	
lrgdp	-0.0784**	0.1016*	0.6906***	0.7010***	-0.6906***	1

Note: ***, ** and * indicate that the coefficient is significantly different from zero at 1, 5 and 10 percent level of significance, respectively.

Table 4. The real exchange rate change and real export growth

Variables	(1) ΔE	(2) ΔE	(3) ΔE	(4) ΔE
ΔRER	0.55355***	1.17385***	0.50986***	1.22717***
	(0.10841)	(0.18489)	(0.15084)	(0.24510)
ΔRER*mr		-1.51191***		-1.59301***
		(0.43240)		(0.43134)
ΔRER*mer			6.37270	-2.92327
			(6.84597)	(7.51276)
Lagged GDP	-0.10502	-0.10800	-0.10024	-0.11035
	(0.09053)	(0.08972)	(0.09482)	(0.09249)
Constant	2.81127	2.89115	2.68478	2.95346
	(2.36687)	(2.34463)	(2.48010)	(2.41763)
Time fixed effects	y	y	y	y
Country fixed effects	y	y	y	y
Observations	640	640	640	640
R-squared	0.21046	0.21789	0.21109	0.21800
Number of countries	40	40	40	40

Note: Cluster at country level and robust standard error is shown in parentheses.
***, ** and * indicate that the coefficient is significant at 1, 5 and 10 percent level of significance respectively.

Figure 1. Domestic production ratio (2010)

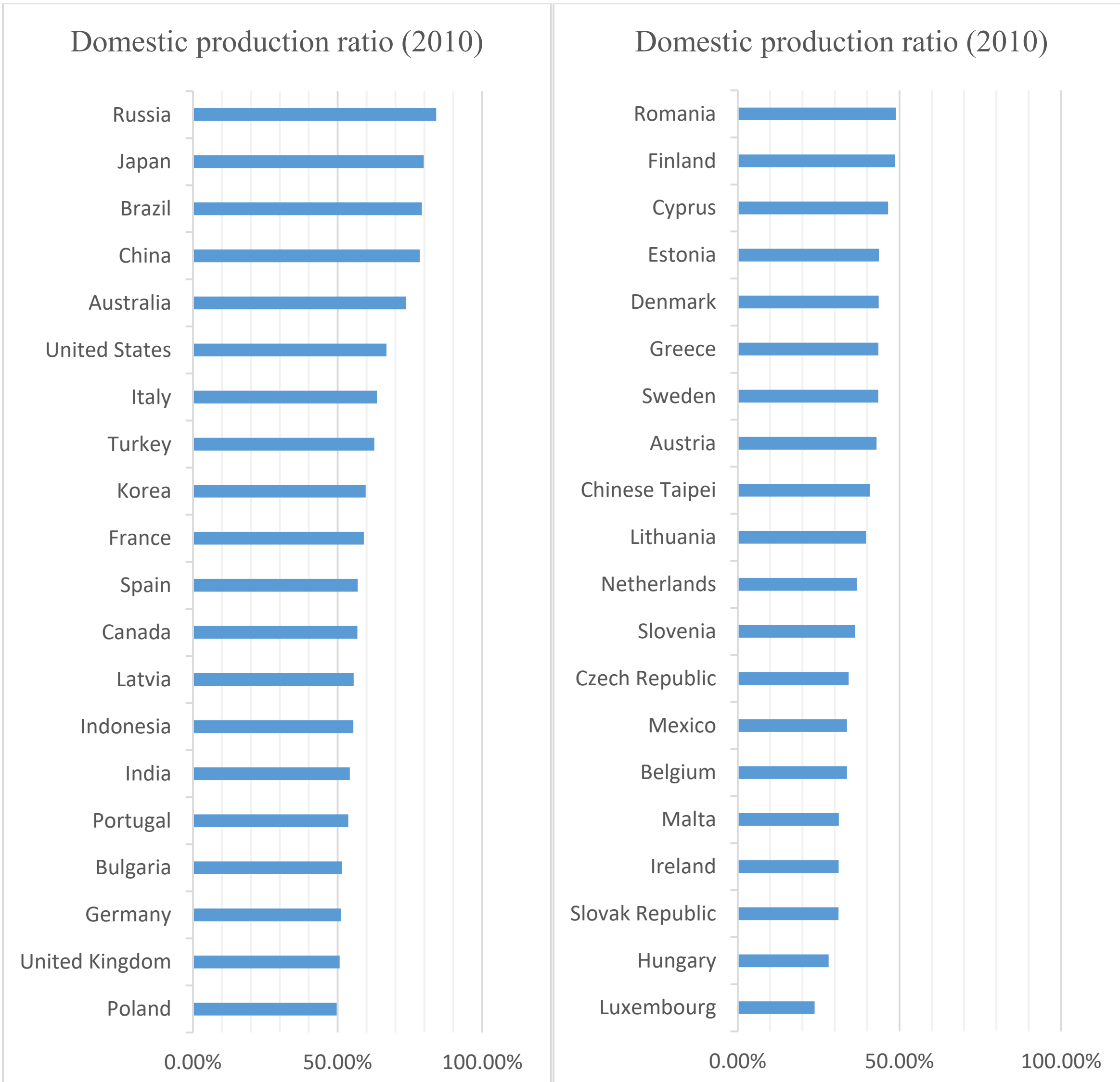
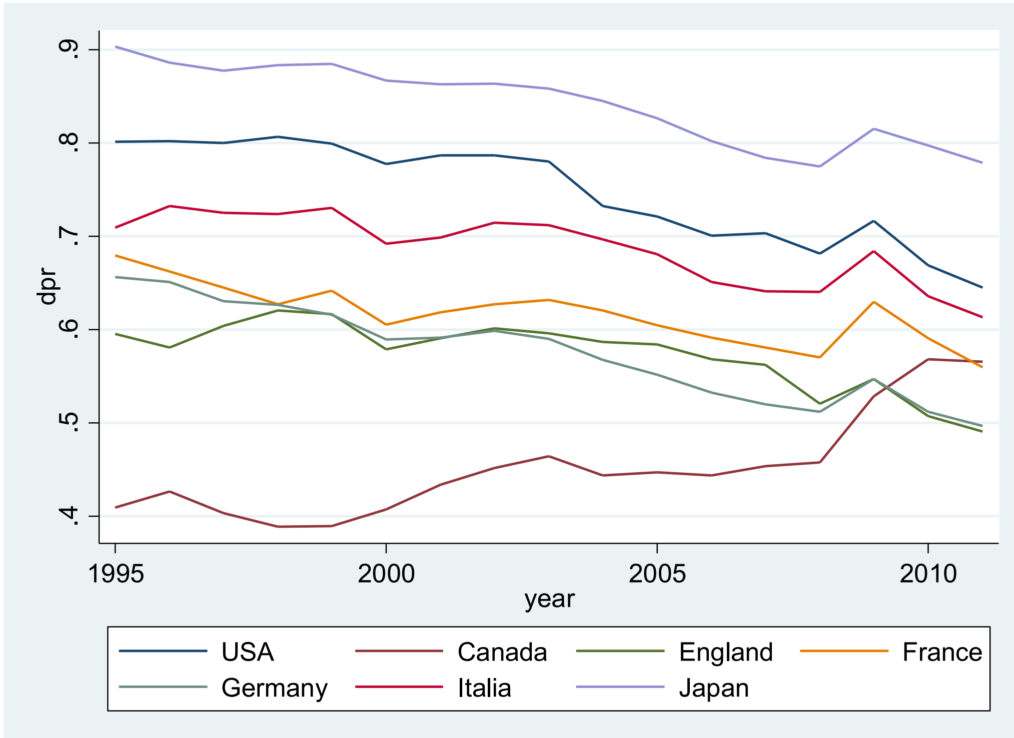


Figure 2. Domestic production ratio over time



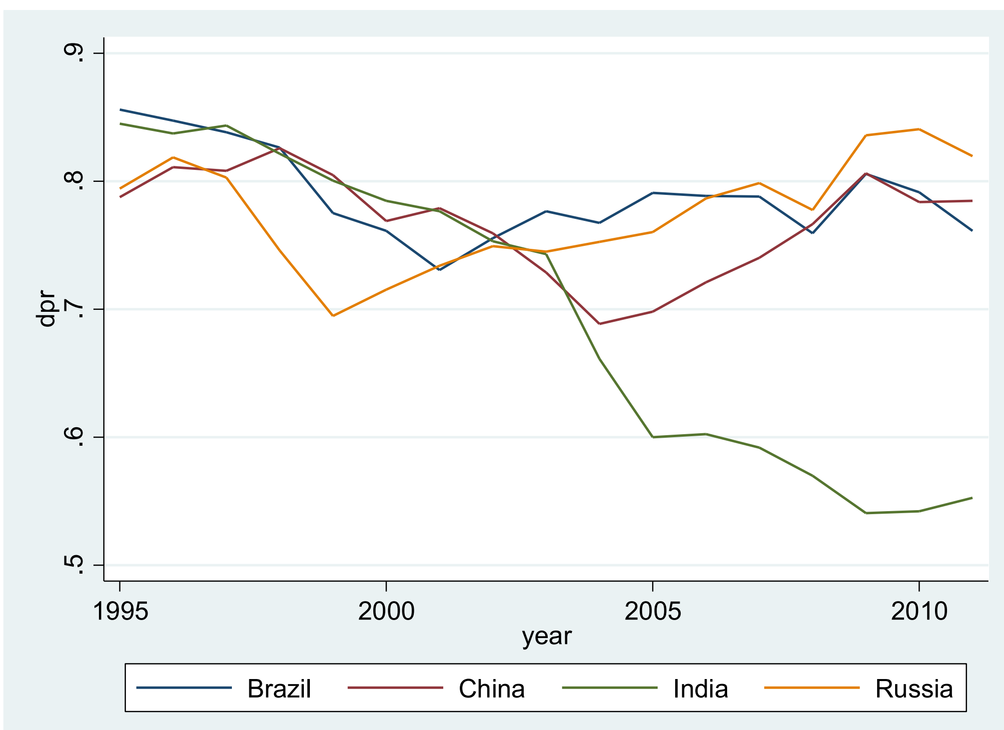
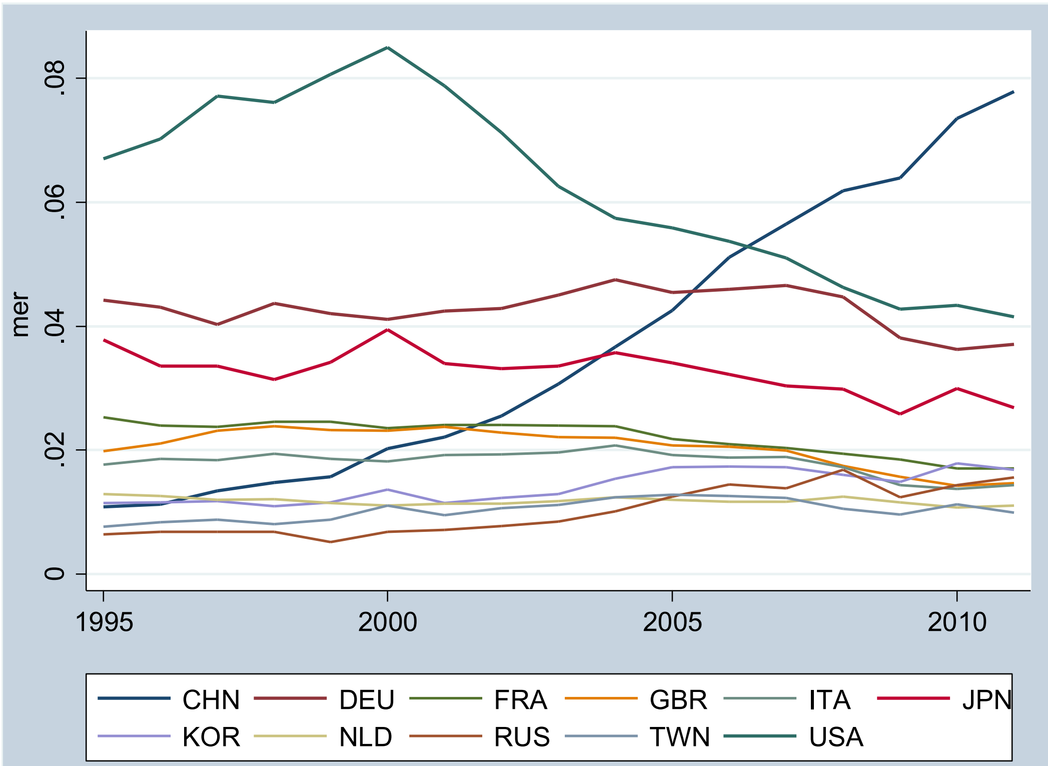


Figure 3. Ratio of exported intermediates of one country to total intermediates used to produce exports of other countries (top highest ratios)



Appendix B

Data Sources

Total exports (goods and services)	World Input-Output Database
Real effective exchange rate (REER)	Bank for International Settlements
Real GDP	World Development Indicator, National sources
Consumer Price Indices	International Monetary Fund, National sources
Exchange rate (local currency/USD)	Penn World Table

List of countries

Australia, Austria, Belgium, Bulgaria, Brazil, Canada, China, Cyprus, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Indonesia, India, Ireland, Italy, Japan, Korea, Lithuania, Luxembourg, Latvia, Mexico, Malta, Netherlands, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Sweden, Turkey, Chinese Taipei, United States.

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